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Community structure and longitudinal patterns of benthic invertebrates in a heavy-metal contaminated Alaskan river system

Brown, Barry Neil, M.Sc.

University of Alaska Fairbanks, 1987

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COMMUNITY STRUCTURE AND LONGITUDINAL PATTERNS OF BENTHIC

INVERTEBRATES IN A HEAVY-METAL CONTAMINATED ALASKAN RIVER SYSTEM

RECOMMENDED: Jacqueline D. LaPerriere

W Scott Armbruster

Neal L Oswood

Chairman, Advisory Committee

Robert B Weeden

Head, Dept. of Biol., Wildl. and Fish.

Dean, College of Natural Sciences

APPROVED:

Director of Graduate Programs

31 March 1987

Date

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COMMUNITY STRUCTURE AND LONGITUDINAL PATTERNS OF BENTHIC

INVERTEBRATES IN A HEAVY-METAL CONTAMINATED ALASKAN RIVER SYSTEM

A

THESIS

Presented to the Faculty of the University of Alaska

in partial fulfillment of the requirements

for the Degree of

MASTER OF SCIENCE

By

Barry Neil Brown, B.S.

Fairbanks, Alaska

May 1987

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ABSTRACT

Community structure of stream invertebrates was investigated in a heavy-metal contaminated watershed in Denali National Park, Alaska. Three sites were located on Stampede Creek, with one station above an antimony mine (active 1916-1970) and two stations below. An additional site was located on the Clearwater Fork of the Toklat River downstream from the Stampede Creek confluence. Quantitative samples of benthic invertebrates and associated coarse (> 1 mm) detritus were obtained in late June (early spring), late July (summer), and late August (early fall).

Gut analyses allowed categorization of insects to functional feeding groups. Water temperatures increased and detrital storage generally decreased downstream. Abundance of shredders was positively correlated with abundance of coarse detritus at the headwater site. Longitudinal changes in functional group composition were consistent with the River Continuum Concept. Heavy metal contamination appeared to affect taxonomic and functional groups differentially. Grazers and predators were severely underrepresented directly downstream from the mine.

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INTRODUCTION

High Latitude Stream Ecology

In this study I describe the benthic community composition of a subarctic interior Alaskan river system. Compared with temperate streams little is known about the ecology of high latitude streams (Harper 1981). There is a paucity of information about the distribution and life histories of major insect taxa found in high latitude streams (Howe 1981; Irons 1985). The few quantitative studies of stream benthos in interior Alaska (e.g. Slack et al 1979; Cowan 1983; EVS Consultants 1983; Cowan and Oswood 1984; Oswood et al 1984) have shown impoverished faunas typical of northern ecosystems .

The River Continuum Concept

The River Continuum Concept is a major paradigm of lotic ecology in which the entire stream-to-river complex is conceptualized as one ecosystem (Vannote et al 1980). This longitudinally linked ecosystem is composed of a series of communities along a continuum. The structural and functional characteristics of these communities change predictably along the course of a river as a result of continuously changing gradients of physical and biological conditions (Minshall et al 1983). The structure and function of macroinvertebrate communities are influenced by variations in autochthonous and allochthonous organic matter inputs down the length of

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rivers (Cummins 1974). Allochthonous organic matter enters the stream partly as coarse particulate organic matter (CPOM, particles > 1mm, mainly leaves, twigs, bark and fruits) (Cummins 1974) and is most important in headwater forested sections, where the stream is shallow, narrow and shaded by trees. Further downstream, allochthonous matter is primarily in the form of fine particulate organic matter (FPOM, particles < 1mm) as a result of transport from upstream and input from the surrounding, less heavily wooded riparian zone. Autochthonous organic matter consists of attached algae and the organic layer associated with the substratum, and increases in importance downstream as the stream widens, shading becomes less intense and algal production increases (Cummins 1974; Vannote et al 1980). Ecosystem level processes in downstream areas are linked to those in upstream areas (Minshall et al 1985). Applicability of the River Continuum Concept to regions other than temperate North America, however, has been questioned (Winterbourne et al 1981; Statzner and Higler 1985).

In this study I examine changes in community structure of benthic invertebrates along contiguous sites from a first order headwater stream to a fifth order river. Community structure refers to the number of taxa, their absolute and relative abundance in a community, and their apportionment into feeding guilds (Hawkins et al 1982) or functional groups (Cummins 1974). Feeding guilds describe the strategies that aquatic invertebrates have evolved to utilize food resources and also what resources are eaten (Hawkins et al 1982). Functional groups are based on the morphological and behavioral capacity of stream insects to consume available food resources, and are partially independent of taxonomic determinations (Cummins and Klug 1979).

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In this study I determine if there were shifts in the relative dominance of functional feeding groups in accordance with changes of stream physical characteristics and biological resources. Correlation between benthic invertebrate abundance, and shredder abundance, with coarse (> 1mm) benthic detritus was tested. In addition, correlation between predator functional group abundance with prey abundance (all benthic insect taxa which are not predators) was tested. This study tests some of the predictions of the River Continuum Concept, while a comparison between these high latitude sites and temperate sites provides a test of the generality of the predictions of the River Continuum Concept.

Effects of Heavy Metals

Heavy metal is a term generally applied to those metals with a density greater than five (Passow et al 1961). This definition includes about forty elements. The contamination of streams and rivers from heavy metals is particularly dangerous due to the toxicity of these compounds at very low concentrations, and because they are not biodegradeable (Forstner and Wittman 1981). Heavy metals enter streams and rivers from the weathering of soils and rocks, volcanic eruptions, and human activities involving the mining, processing, or use of metals and metal containing substances (Laws 1981). Depending on environmental conditions, heavy metals may change the density, diversity, community structure and species composition of stream organisms (Moore and Ramamoorthy 1984).

In this study I examine the effects of chronic, long term exposure to heavy metals on a subarctic benthic invertebrate stream community. The

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gradient approach establishes a reference site upstream of the pollution source and other sites downstream at various distances from the point-source input. This approach has significant advantages over other methods (e.g. those that use reference sites in a different watershed) for the analysis of benthic invertebrate community response to increasing and declining pollutant concentrations (Sheehan and Winner 1984). This study includes one site above and several study sites below a source of heavy metal contamination (the Stampede antimony mine). I expected that effects on benthic invertebrates would be greatest immediately below the source of heavy metal contamination and decrease further downstream. The effects of naturally occurring high levels of heavy metals within the study area on the benthic invertebrate community is examined by comparison with other interior Alaskan benthic invertebrate communities in streams where natural occurrence of heavy metals is less.

There is a great need for studies which deal with the effects of toxic compounds on higher levels of biological organization such as populations, communities and ecosystems (Hartung 1973; Sheehan 1984a; Leland and Kuwabara 1985). The applicability of laboratory toxicity tests to naturally occurring situations is unresolved (LaPoint et al 1984). One drawback of laboratory tests is the difficulty of running experiments for long periods and therefore the danger of entirely overlooking the properties of toxins that act slowly (Hynes 1963). Too often with toxicity tests it is implicitly assumed that single species toxicity tests enable predictions to be made about responses at the community or ecosystem level (Cairns 1983), when, in fact, the ecosystem possesses characteristics which reflect the integrated response of many component populations (Sheehan 1984b).

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Pollutant-caused perturbations have the potential to influence all components of the ecosystem, although impacts on a single species may have negligible effects on system function (Sheehan 1984a). In this study I determine if heavy metal contamination of a river system adversely affects all taxonomic groups and functional feeding groups uniformly or if particular taxonomic and functional feeding groups are differentially affected.

Study Site History

The four study sites are along a watershed within the Kantishna Hills, a range of low mountains less than 1600 m in elevation, in the north central portion of Denali National Park and Preserve. Three of the study sites are on Stampede Creek, one above the Stampede antimony mine and two below, and one study site is on the Clearwater Fork of the Toklat River directly below its confluence with Stampede Creek (Figure 1). Other studies of the Kantishna Hills area have described the geology and mineral deposits (Bundtzen 1981), the heavy metals in streams and rivers (West 1982; West and Deschu 1984), and the abundance and distribution of fish (Meyer and Kavanagh 1983).

The Stampede antimony mine and the surrounding watersheds became part of the Park through the 1980 Alaska National Interest Lands Conservation Act which expanded the boundaries of Denali National Park and Preserve. The United States Congress will review the results of a five year study (the Final Environmental Impact Statement, U.S. Dept. of the Interior 1984) of this mineralized area in the Kantishna Hills to decide upon a land

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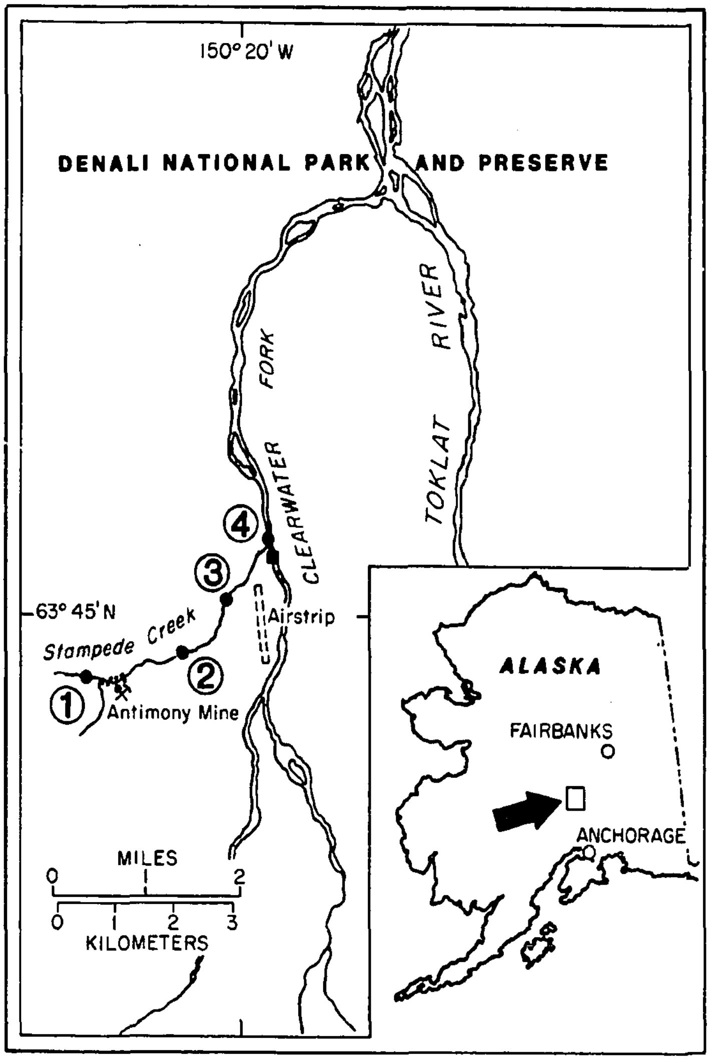

Figure 1. Map of study area and study sites. Site upstream of site 4 on the Clearwater Fork shows additional site for heavy metal sampling by West (1982) and West and Deschu (1984).

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use management plan. Some of the factors that lead to multiple use conflicts in this situation include water quality, fisheries resources, and aesthetic values. Options range from opening up new areas for mining to buying out miners and discontinuing present mining activity (Hunter 1985).

All streams in the Kantishna Hills are naturally clear coming from snowmelt, rainfall, and subsurface aquifers rather than glacial meltwater (Meyer and Kavanagh 1983). Since the discovery of placer gold in 1905, the Kantishna Hills has been an active mining area noted for lode deposits of antimony, copper, gold, lead, silver, and zinc. Development work on the Stampede antimony deposit began in 1916 but active mining began in 1936 and antimony shipments from the mine peaked during World War II when the Stampede mine was Alaska's largest antimony producer (Bundtzen 1978). Antimony production continued until 1970, and in the late 1970's the mine and buildings were donated to the University of Alaska, Fairbanks. There has been gold placer mining activity along Stampede Creek in the early 1900's and again during 1947 to 1949 (Meyer and Kavanagh 1983). Other sporadic disturbances to the stream are from construction activities and road building associated with the antimony mine. Clearwater Fork has no gold placer claims but may have had some placer mining in the early 1900's and definitely had some on three tributaries (Meyer and Kavanagh 1983).

Study Site Description

Stampede Creek starts out as a small headwater stream and becomes a second order stream as it flows 4.6 km to its confluence with Clearwater Fork. Clearwater Fork is a large (occasionally 0.8 km wide) fifth order

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river. The average gradient of Stampede Creek is 36 m/km and the average gradient of Clearwater Fork is 12.5 m/km (Meyer and Kavanagh 1983). Both Stampede Creek and Clearwater Fork are clear-flowing along their entire lengths.

Site 1 is 0.4 km above the Stampede Mine on the upper reach of Stampede Creek. Site 1 has had no apparent mining activities or disturbances. It is a headwater stream with a closed riparian canopy of willow, alder and black spruce. The stream channel is narrow (1-3 m wide) with a steep gradient and several deep pools. The substrate is mostly boulder and rubble with some gravel, sand, silt and woody material. Sites 2 and 3 are 0.5 km and 1.0 km respectively, below the mine on the middle reach of Stampede Creek and both have been subjected to mining activities and disturbances. The sites are shallow and narrow, with few pools, flowing through a wide braided floodplain. The stream is unshaded with no canopy since one streambank has sparse, scattered willows and grasses, and the other streambank is bare and rocky and parallels the road between the mine and airstrip. The substrate contains fewer boulders and more rubble and gravel compared to site 1. Immediately below the mine, and continuing for some distance, including site 2, the substrate has a reddish coating. This is probably the result of leached iron (Robin West, personal communication). At site 4 on the Clearwater Fork the river channel is wide (about 50 m) and unshaded with northern boreal forest on each riverbank consisting of mostly white spruce, willows, alder, and scattered paper birch and poplar. The aquatic habitat consists mostly of riffles and rapids with few pools. The water is often deep (> 1 m) and the substrate is boulder, rubble and gravel.

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Table 1 summarizes some basic physical characteristics of each study site. Temperatures were very low at all sites, but on all sampling dates were consistently lowest at site 1 and were progressively higher at each site downstream up to the maximum temperatures at site 4. The pH was high and did not vary much between sites. Hardness and alkalinity were relatively high for sites 1-3 on Stampede Creek (compared with other streams in nearby watersheds) (West and Deschu 1984) and decreased at site 4 on Clearwater Fork. Turbidity was much higher at site 4. Discharge increased progressively from site 1 through 3 and was not measured for site 4 but was undoubtedly much higher.

Determinations of heavy metal concentrations were made at the same site locations on Stampede Creek and the Clearwater Fork by West (1982), and West and Deschu (1984). One sample was taken at each site on 5 August 1982, 7 July 1983 and 26 August 1983. West (1982), and West and Deschu (1984) compared heavy metal concentrations of individual samples with three water quality standards: Alaska Drinking Water Maximum Contaminant, U.S.E.P.A. Water Quality Criteria for Human Health, and U.S.E.P.A. Criteria for Protection of Freshwater Aquatic Life. Heavy metal concentrations of individual samples exceeded one or more of these water quality criteria for the following metals: antimony, copper, iron, manganese, nickel, cadmium, arsenic, mercury, and zinc. The very small sample sizes of these studies does not allow examination of variance associated with sampling, storage and determination procedures, seasonality or stream flow, and a much more extensive investigation would be required to relate such variability to water quality criteria. Nonetheless, all the watersheds in the Kantishna Hills have elevated levels of some heavy metals (West and Deschu 1984)

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Table 1. Physical characteristics of study sites.

	Site 1	Site 2	Site 3	Site 4
Stream Order	1st	2nd	2nd	5th
Elevation	600 m	585 m	555 m	540 m
Above or Below Mine	Above	Below	Below	Below
Distance From Mine	0.4 km	0.5 km	1.0 km	2.5 km
June Water Temp.	1.7° C	5.5°C	9.5°C	10.2°C
July Water Temp.[1]	4.5°C	6.6°C	11.2°C	12.5°C
August Water Temp.[1]	3.2°C	5.8°C	----	6.5°C
pH[2]	7.62	7.64	7.76	7.77
Hardness (mg/l)[2]	372.0	382.0	315.0	186.0
Alkalinity (mg/l)[2]	150.0	142.0	114.0	97.0
Turbidity (NTUs)[2]	2.0	1.4	3.8	14.5
Settleable Solids[2]	<0.1	<0.1	<0.1	<0.1
Discharge (cfs)[2]	2.29	4.31	8.36	----

[1] This study averaged with data from West and Deschu (1984).
[2] From West and Deschu (1984), July and August data.

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resulting from natural mineralization and mining. The tailings of the Stampede Mine appear to leach heavy metals as there is a marked increase in heavy metals found at stream sites below (West 1982; West and Deschu 1984). Generally, heavy metal concentrations were lowest at site 1 above the mine and highest at site 2 directly below (0.5 km) the mine, and intermediate at site 3 further down (1.5 km) below the mine. Site 4 on Clearwater Fork, below the confluence with Stampede Creek, seems to be affected by Stampede Creek's elevated heavy metal concentrations as evidenced by West and Deschu (1984) who took samples from site 4 and from another site on Clearwater Fork directly above the confluence (Figure 1) and often found site 4 to show higher heavy metal concentrations than the upstream site.

The data of West (1982), and West and Deschu (1984) were further analyzed (Brown and Oswood 1985) by comparing total (unfiltered) heavy metal concentrations among the four sample sites using the Kruskal-Wallis test (a non-parametric one-way analysis of variance). Three metals showed significant differences between sample sites (Table 2): antimony, manganese and selenium. Both antimony and manganese showed a longitudinal pattern consistent with derivation from the mine, that is, an increase in concentration directly below the mine followed by a downstream decrease. Selenium shows the highest concentration at site 1 (above the mine) with declining downstream concentrations apparently indicating a localized source of selenium in the upper valley.

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Table 2. Mean (n=3) concentrations of total (unfiltered) heavy metals showing significant ($P < 0.05$) differences between sample sites (from Brown and Oswood, 1985). All values in mg/l. Based upon data from West (1982) and West and Deschu (1984).

	Site 1	Site 2	Site 3	Site 4
Antimony	0.037	0.207	0.186	0.058
Manganese	0.0077	0.0468	0.0203	0.0203
Selenium	0.0014	0.0009	0.0005	0.0005

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METHODS AND MATERIALS

BENTHIC SAMPLING

Benthic samples from six randomly selected locations were taken at each study site during three sampling periods in 1981: late June (early spring, soon after break-up with large ice shelves still covering part of site 1), late July (summer), and late August (early fall, not long before freeze-up with autumnal leaf fall well advanced at all sites). A Portable Invertebrate Box Sampler (Ellis and Rutter Associates, see Merritt and Cummins 1984) was used for benthic sampling. For sampling deep water (up to 0.8 m) a collapsible sheet metal extension was attached to the top of the box sampler. The box sampler encloses a substrate area of 0.1 m^2. The substrate was stirred by hand to a depth of approximately 10 cm and dislodged invertebrates and detrital particles were swept by the current into the net until very few particles were visible in the enclosed water column. On the first sampling date all study sites were sampled with an auxiliary 0.08 mm mesh net attached to the standard 0.360 mm mesh net on the box sampler. In the laboratory, an experiment was performed to determine differences in size and type of organisms caught by the 0.08 mm and 0.360 mm nets. Differences were very slight and on the remaining two sampling dates the 0.360 mm mesh net alone was used. Samples were preserved immediately in the field with Kahles solution. Appendix A lists the date, location and substrate type (erosional or depositional) of each sample.

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INVERTEBRATE ABUNDANCE AND FUNCTIONAL GROUP DESIGNATION

All samples were transferred to 95% ethanol in the lab and examined under a dissecting microscope. Organisms were sorted and identified to the lowest practical taxonomic level. Each taxon was counted and its biovolume was determined. Biovolume is estimated by volumetric displacement of ethanol in a pipette and is comparable to biomass (Cowan et al. 1983), and allows further use of specimens for gut analyses and taxonomic purposes.

Gut analyses were performed on subsamples of each major taxon (except the Chironomidae). The method used was similar to that of Cowan (1983). The foregut was removed from each randomly selected specimen and its contents dissected and teased apart in distilled water. Gut contents were retained by passage through a 0.00045 mm pore size membrane filter. Dried filters were cleared with immersion oil on a microscope slide and secured with a cover slip. Slides were examined at 100x and 400x and the relative surface area of algae, coarse detritus (>1 mm), fine detritus (< 1mm), and animal material was estimated to the nearest 20% of total particle surface area. The number of guts examined from each taxon was roughly proportional to the number of specimens available.

All taxa were assigned to functional feeding groups (Cummins and Klug 1979) based on the results of these gut analyses or by designations of Merritt and Cummins (1984). In this study I used the following functional groups: shredders (feed by shredding coarse detritus, >1 mm), collector/gatherers (feed by collecting depositional fine detritus, <1 mm), grazers (feed by scraping periphyton), filter-feeders (feed by filtering

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seston), and predators (feed by engulfing prey). Most chironomid larvae encountered were extremely small and no gut analyses were performed. Chironomid larvae span every functional group (Coffman and Ferrington 1984), but those found in interior subarctic streams are probably collector/gatherers (Oswood et al 1984).

DETRITUS

To find the amount of coarse detritus (>1 mm) in each sample the woody, refractory material (e.g. twigs, roots),and organisms were first picked out. Then the sample was gently rinsed repeatedly through a 1 mm sieve. The retained material was dried at 50°C for 48 hours, cooled, weighed, then burned in a muffle furnace at 500°C for 12 hours and then cooled and weighed again. This provided the ash-free dry weight (AFDW) of the coarse particulate organic matter (CPOM) contained in each sample.

STATISTICAL METHODS

Differences in numerical abundance (number/m^2) or biovolume (ml/m^2) of benthic organisms between sites were tested using a non-parametric one-way analysis of variance (Kruskal-Wallis test). Data from each of the three sampling times (seasons) were analyzed separately. Sample size (n) for all tests was 24 (4 sample sites x 6 samples/site/date).

Correlations between biovolume of shredders and amount of coarse detritus, between biovolume of all organisms and amount of coarse detritus, and between biovolume of predators and biovolume of prey (all benthic

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insect taxa which are not predators) were tested using a non-parametric test (Spearman Rank Correlation). Data from each site and from each of the three sampling times (seasons) were analyzed separately (n=6). Data from each site with all seasons combined were also analyzed (n=18). Each site was analyzed separately due to the great variability found between sites.

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RESULTS

Benthic Invertebrates

Table 3 lists all the taxa identified and the sites where they were found. Site 4 has the greatest number of unique taxa: Pseudocleon, Ephemerella, Serratella, Dixidae, Glossosomatidae, and Cladocera were found only at site 4. Appendix B lists the numerical abundance and Appendix C the biovolume abundance of taxa found in each sample.

Table 4 shows the results of gut analyses and the designation of functional feeding group for benthic insects. Appendix D lists each individual gut analysis. There is remarkably little variation found in the diet of each taxon. Shredders almost all had 100% CPOM in their guts, collector/gatherers almost all had 100% FPOM in their guts, and predators almost all had 100% animal material in their guts. Only grazers exhibited appreciable variation in food materials.

The longitudinal distribution of major shredder taxa is shown in figure 2. All of them are nemourid stoneflies except Tipula (Diptera). Podmosta and Zapada showed greatest abundance at site 1. Podmosta occurred in greatest numbers in spring and was not found in fall. Nemoura was numerically dominant and found mostly at site 2. Shredder biovolume differed significantly between sites during all seasons and was consistently highest at site 2 and site 1. Shredders were in very low abundance at site 4.

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Table 3. Taxa List and Presence/Absence at Study Sites

	Site 1	Site 2	Site 3	Site 4
Plecoptera:				
Nemouridae				
Nemoura	X	X	X	X
Podmosta	X	X	X	
Zapada	X	X		
Chloroperlidae	X	X	X	X
Perlodidae	X	X	X	X
Capniidae	X	X	X	X
Taeniopterygidae			X	X
Ephemeroptera:				
Baetidae				
Baetis	X		X	X
Pseudocleon				X
Ephemerellidae				
Ephemerella				X
Serratella				X
Heptageniidae				
Cinygmula	X	X	X	X
Epeorus		X		X
Siphlonuridae				
Ameletus	X	X		
Diptera:				
Chironomidae	X	X	X	X
Simuliidae				
Gymnopais	X	X		
Prosimulium	X	X	X	X
Tipulidae				
Tipula	X	X	X	X
Dicranota	X	X		X
Ormosia	X			
Gonomyodes	X			
Empididae	X	X	X	X
Ceratopogonidae		X	X	

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Table 3. continued. Taxa List and Presence/Absence at Study Sites

	Site 1	Site 2	Site 3	Site 4
Psychodidae	X	X		
Muscidae		X		
Dixidae				X
Trichoptera:				
Limnephilidae	X	X		X
Glossosomatidae				X
Misc. Taxa:				
Collembola	X	X	X	X
Oligochaeta	X	X	X	X
Nematoda	X	X		
Platyhelminthes	X	X	X	
Hydracarina	X	X	X	X
Copepoda	X	X	X	X
Cladocera				X

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TABLE 4. Gut analyses and functional group designation of benthic insects. Contents were estimated as percent of total particulate surface area. n = number of individuals in each analysis; tr = trace amount.

Functional Group/ Taxa	Sample (n)	Season	Average Gut Contents % CPOM	% FPOM	% Diatom	% Animal
Shredders:						
Zapada	2	Spring	100		tr.	tr.
Zapada	3	Summer	100			
Podmosta	3	Spring	100			
Podmosta	3	Summer	100			
Nemoura	2	Spring	100			tr.
Nemoura	2	Summer	tr.	100		
Nemoura	4	Fall	100			
Ephemerella	1	Spring	100		tr.	
Ephemerella	2	Fall	100		tr.	
Tipula	2	Spring	100			
Tipula	1	Summer	100			tr.
Tipula	3	Fall	100			
Ormosia	2	Summer	100			
Gonomyodes[1]						
Tipulidae[1]						
Limnephilidae[1]						
Collector-Gatherers:						
Capniidae	2	Spring	50	50		tr.
Capniidae	2	Summer	tr.	100	tr.	
Capniidae	2	Fall		100	tr.	
Taeniopterygidae	6	Fall		100	tr.	
Ameletus	2	Spring		100	tr.	
Ameletus	2	Summer		100	tr.	
Ameletus	2	Fall		50	50	
Epeorus	1	Spring		60	40	
Epeorus	1	Summer		100	tr.	
Epeorus	2	Fall		90	10	
Cinygmula	2	Spring		100	tr.	
Cinygmula	2	Summer		100	tr.	
Cinygmula	2	Fall		90	10	

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TABLE 4. continued. Gut analyses and functional group designation of benthic insects. Contents were estimated as percent of total particulate surface area. n = number of individuals in each analysis; tr = trace amount.

Functional Group/ Taxa	Sample (n)	Season	Average Gut Contents % CPOM	% FPOM	% Diatom	% Animal
Collector-Gatherers continued:						
Chironomidae[1]						
Psychodidae[1]						
Dixidae[1]						
Grazers:						
Baetis	2	Spring		25	75	
Baetis	1	Summer		80	20	
Baetis	2	Fall		75	25	
Pseudocleon[1]						
Gymnopais[1]						
Glossosomatidae[1]						
Filter-Feeders:						
Prosimulium[1]						
Predators:						
Isoperla	2	Summer				100
Isoperla	3	Fall				100
Chloroperlidae	2	Spring				100
Chloroperlidae	2	Summer				100
Chloroperlidae	2	Fall				100
Dicranota	3	Spring				100
Empididae	2	Spring				100
Empididae	3	Summer				100
Empididae	1	Fall				100
Ceratopogonidae[1]						
Muscidae[1]						

[1]Merritt and Cummins (1984)

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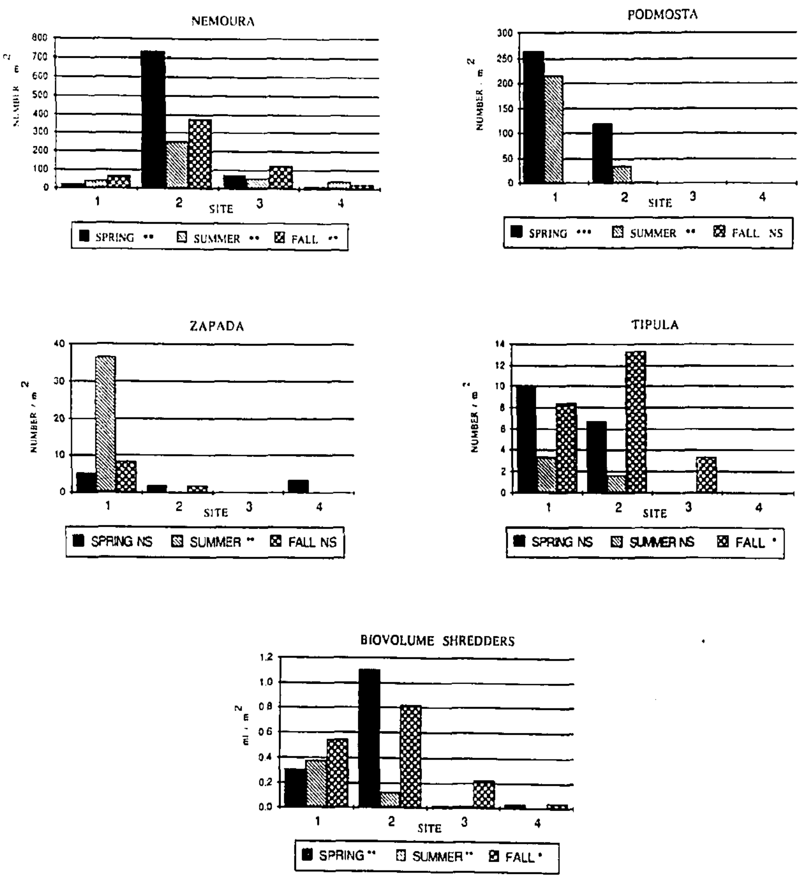

Figure 2. Longitudinal distribution and total biovolume of shredders: Nemoura, Podmosta, Zapada, Tipula. Significance of differences between sites indicated by: NS = not significant (P > 0.05), * = P < 0.05, ** = P < 0.01, and *** = P < 0.001.

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The longitudinal distributions of major collector/gatherer taxa are shown in figure 3. All of them showed significant differences in abundance (in some seasons) between sites, with Capniidae and Amaletus greatest at site 1, and Taeniopterygidae, Cinygmula, and Epeorus greatest at site 4. Capniidae were found in very high density in summer and fall at site 1. Taeniopterygidae were found only in the fall. The biovolume of collector/gatherers was not significantly different between stations in the fall but was in summer and spring. In the spring, site 4 had the highest biovolume, while in the summer site 1 had the highest biovolume. Site 3 had the fewest collector/gatherers in spring and fall, and had essentially none in the summer.

The longitudinal distribution of the two major grazer taxa is shown in figure 4. Baetis differed significantly in abundance between sites in spring and fall with greatest abundance at site 4 and also occurred at site 1 and site 3 but none was found during any season at site 2. Gymnopais (black flies which as larvae lack cephalic fans) was most abundant at site 1 during fall and summer. There was no significant difference in abundance between sites in the spring, and Gymnopais was not found below site 2 in any season. Pseudocleon and Glossosomatidae, the only other grazers, were found in low numbers and only at site 4. The biovolume of grazers showed a significant difference in abundance between sites during fall and spring with peaks at site 1 during fall and site 4 during spring. Grazers are essentially absent at site 2 and in extremely low abundance at site 3.

The longitudinal distribution of major predator taxa is shown in figure 5. Perlodidae occurred mostly at site 4 and Dicranota mostly at site 1.

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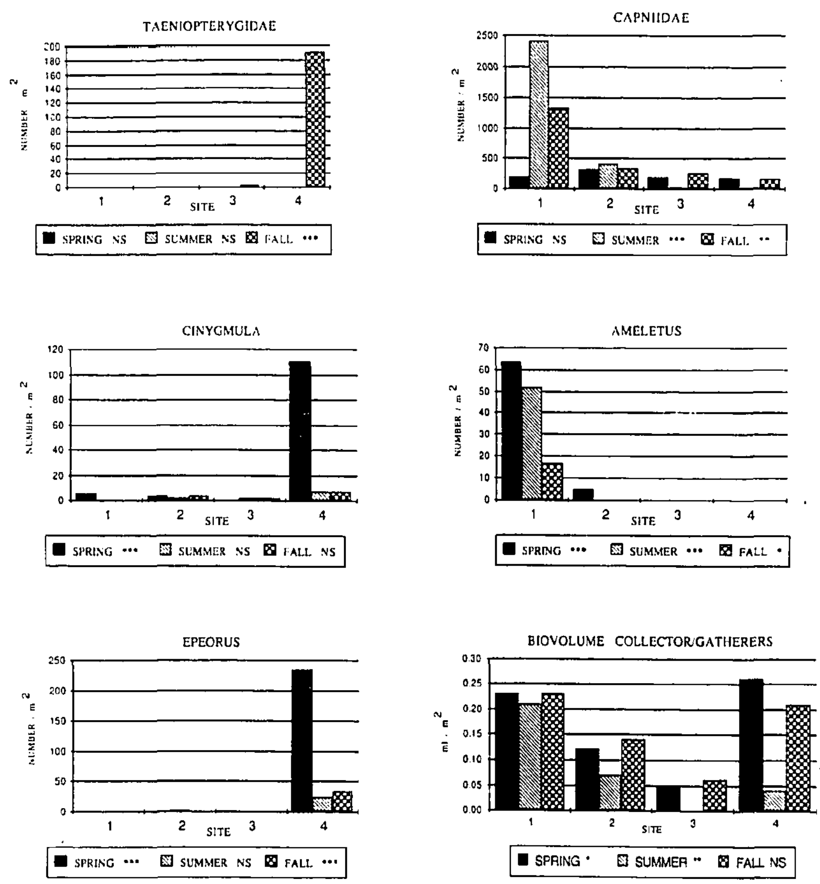

Figure 3. Longitudinal distribution and total biovolume of collector/gatherers: Capniidae, Taeniopterygidae, _Ameletus_, _Cinygmula_, _Epeorus_. Significance of differences between sites indicated by: NS = not significant (P > 0.05), * = P < 0.05, ** = P < 0.01, *** = P < 0.001.

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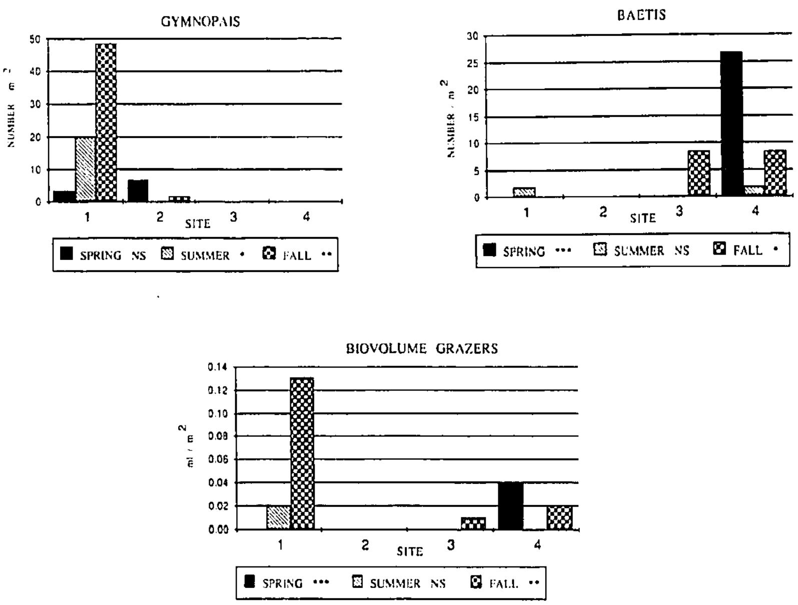

Figure 4. Longitudinal distribution and total biovolume of grazers: <u>Baetis</u>, <u>Gymnopais</u>. Significance of differences between sites indicated by: NS = not significant ($P > 0.05$), * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$.

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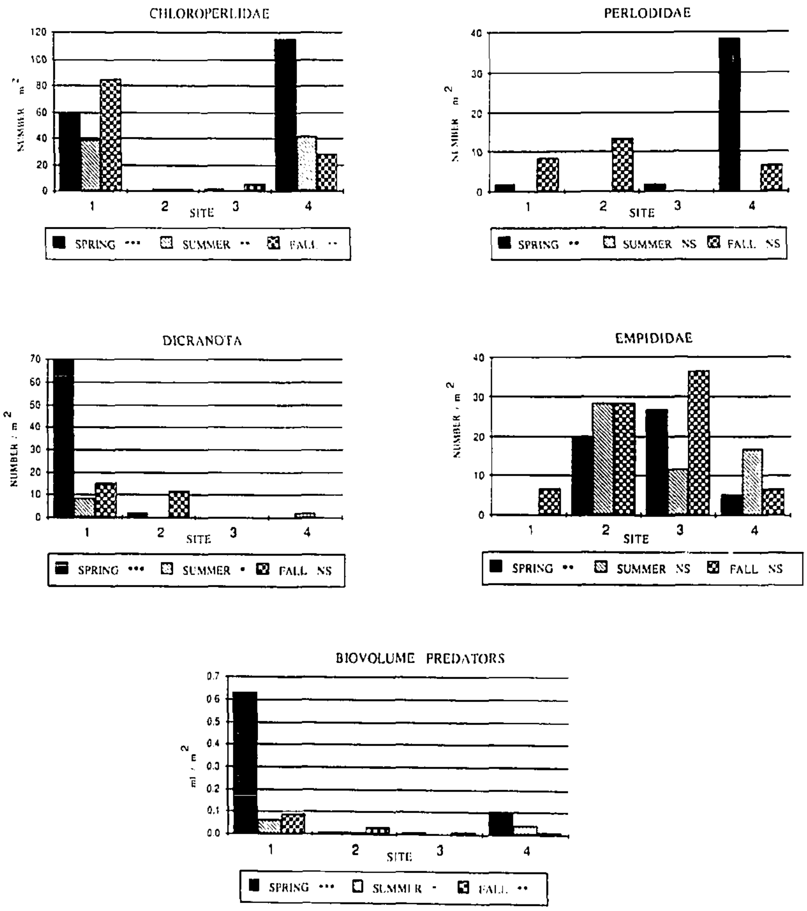

Figure 5. Longitudinal distribution and total biovolume of predators: Chloroperlidae, Perlodidae, Dicranota, Empididae. Significance of differences between sites indicated by: NS = not significant (P > 0.05), * = P < 0.05, ** = P < 0.01, *** = P < 0.001.

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Chloroperlidae were very abundant at sites 1 and 4 and uncommon at sites 2 and 3, while Empididae exhibited the opposite pattern with greatest abundance at sites 2 and 3, and less at sites 1 and 4. Predator biovolume differed significantly between sites for all seasons and was consistently greatest at site 1. Predators were in very low abundance at sites 2 and 3.

Prosimulium was the only filter-feeder found and showed a significant difference in abundance between sites during spring and fall (figure 6). It was found at all sites but in greatest abundance at sites 3 and 4 during spring and fall respectively. In summer Prosimulium was not found at site 4 and was in low abundance at the other sites.

Gut analyses were not performed on Chironomidae. Chironomidae did not show a significant difference in abundance between sites except in summer when they were most abundant at site 1 and showed a progressive decline to site 4 (figure 6).

Table 5 shows the results of a Spearman rank correlation between predator insect biovolume against prey insect biovolume for each site during each season and for each site during all dates combined. Predators showed no significant ($p < 0.05$) correlations with prey.

Figure 7 shows the abundance of Oligochaeta and their percent composition of total benthic invertebrate biovolume at each site. Oligochaeta abundance differed significantly between sites during summer and fall and was consistently greatest at site 1. They were essentially absent at site 4 during all seasons and in greatest abundance at sites 1-3 in fall. Oligochaeta were a major component of total invertebrate biovolume at site 1 and site 2 during summer and fall, and at site 3 during all seasons.

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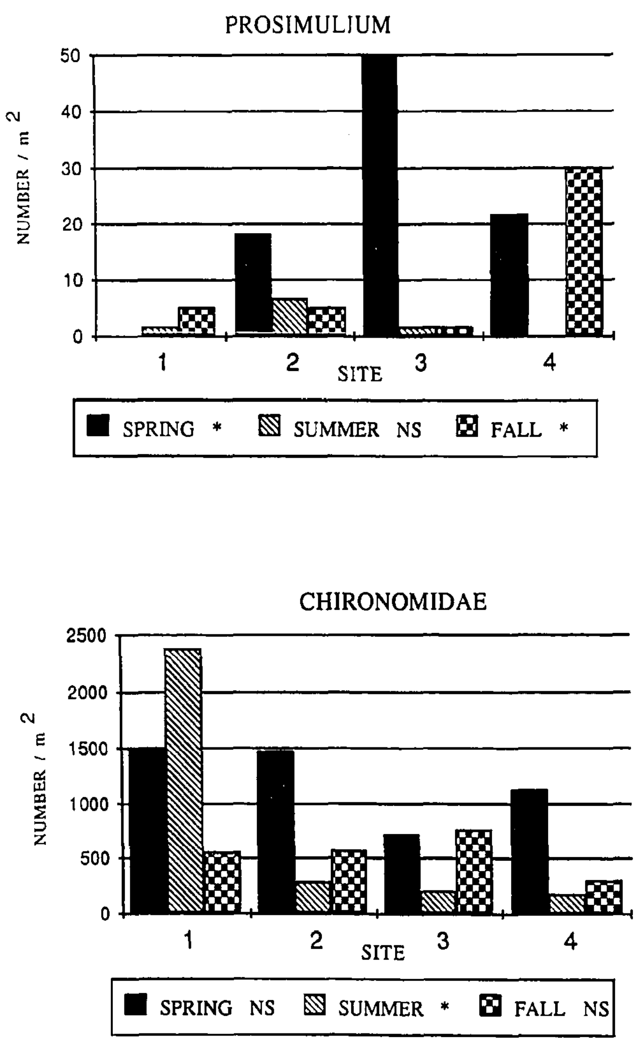

Figure 6. Longitudinal distribution of a filter-feeder taxon: Prosimulium; and of an undetermined functional group taxon: Chironomidae. Significance of differences between sites indicated by: NS = not significant ($P > 0.05$), * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$.

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TABLE 5. Predator insect biovolume (ml/m^2) against prey insect biovolume (ml/m^2). Spearman rank correlation coefficients listed. Significance indicated by: NS = not significant ($p > 0.05$), * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$ (cf. table R, table Q, Sharp 1979). X = no predators found in samples.

	SPRING (n = 6)	SUMMER (n = 6)	FALL (n = 6)	ALL DATES COMBINED (n = 18)
SITE 1	0.600 NS	0.429 NS	0.754 NS	0.267 NS
SITE 2	0.541 NS	0.135 NS	-0.812 NS	0.119 NS
SITE 3	0.338 NS	X	0.247 NS	0.344 NS
SITE 4	0.886 *	0.603 NS	-0.154 NS	0.395 NS

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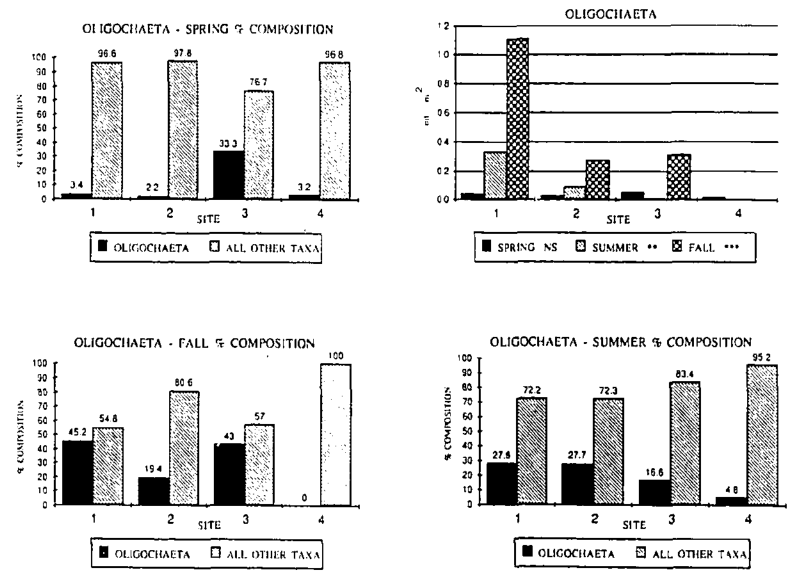

Figure 7. Longitudinal distribution of Oligochaeta. Significance of differences between sites indicated by: NS = not significant (P > 0.05), * = P < 0.05, ** = P < 0.01, *** = P < 0.001. Percent composition by biovolume of Oligochaeta and all other taxa at each site.

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Total benthic insect abundance is shown in figure 8. Benthic insect density (numerical abundance) differed significantly between sites in summer. Greatest abundance occurred at site 1 (then site 2, site 4, site 3). Benthic insect biovolume differed significantly between sites for all seasons. Summer had the same pattern for biovolume abundance as described for density. Fall had greatest biovolume abundance at site 1 with a progressive decrease from sites 2-4. Spring had greatest biovolume abundance at site 2 then site 1 then site 4 then site 3. The density and biovolume of benthic insects, as a seasonal average, was highest at site 1 and decreased progressively from sites 2 to 4.

The relative distribution of the four major insect taxa (Plecoptera, Ephemeroptera, Diptera, and Trichoptera) between the four sites is shown by number and biovolume in figure 9. Both graphs show a similar pattern. Plecopterans and Dipterans were co-dominant at site 1 and site 2. At site 4 they both dropped in biovolume. Trichopterans are essentially absent from all sites. Ephemeropterans were in low abundance at sites 1-3. At site 4 they increased numerically and were dominant in biovolume.

Coarse Detritus

The amount of coarse detritus differed significantly between sites for spring and fall (figure 10). During fall the greatest amount of detritus was found at site 1 with a general progressive decrease from sites 2 to 4. Spring showed a similar pattern except site 4 had a slight amount more than

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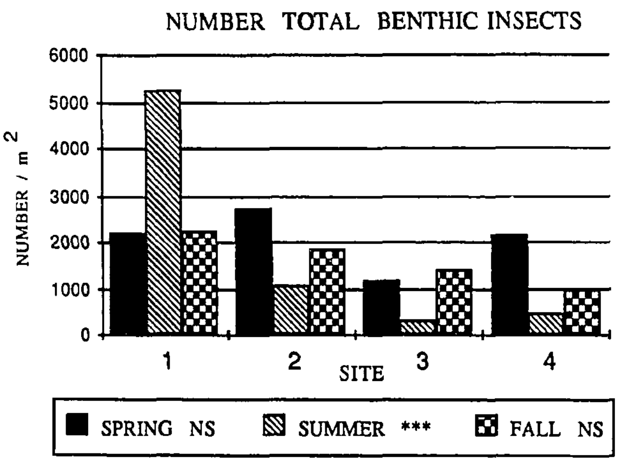

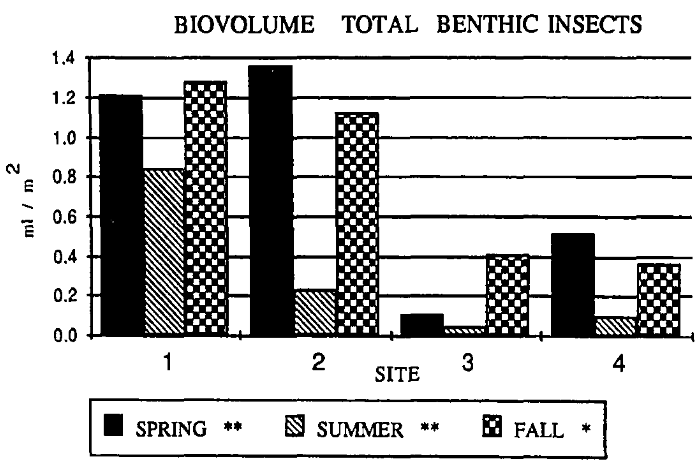

Figure 8. Longitudinal distribution of total benthic insects by numerical abundance and by biovolume abundance. Significance of differences between sites indicated by: NS = not significant ($P > 0.05$), * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$.

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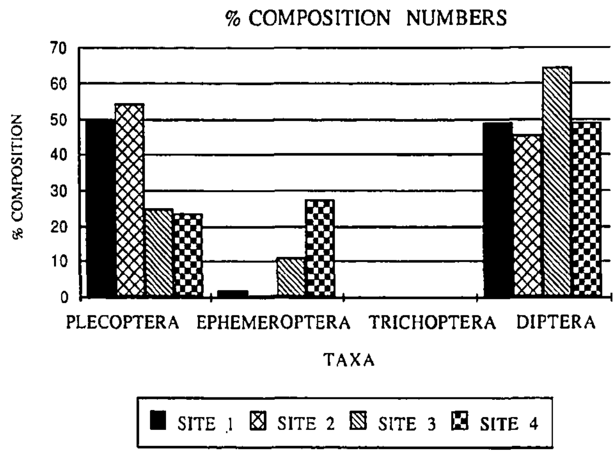

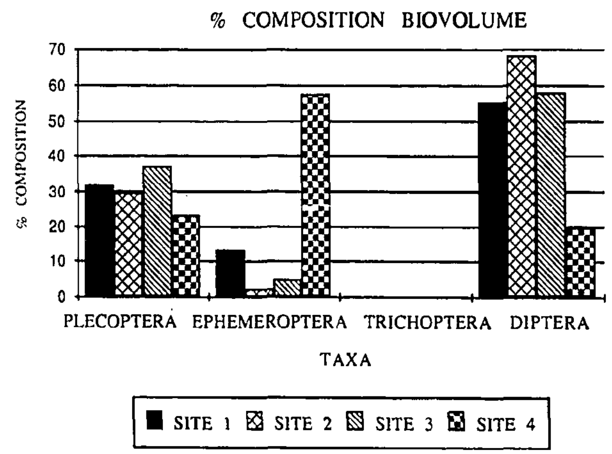

Figure 9. Percent composition by numbers and by biovolume of major insect orders at each site.

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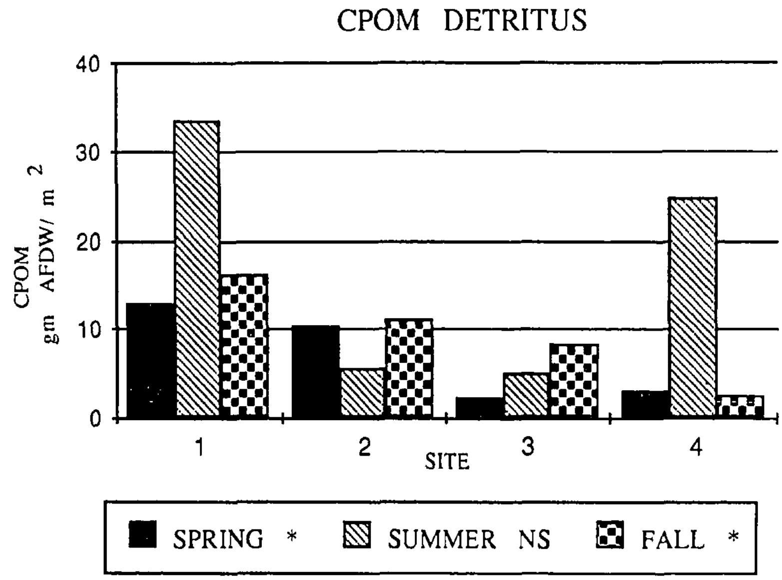

Figure 10. Longitudinal distribution of coarse particulate organic matter (>1 mm) detritus. Significance of differences between sites indicated by: NS = not significant ($P > 0.05$), * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$.

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site 3. During summer, site 4 had a non-significant large increase in coarse detritus.

Tables 6 and 7 show the results of a Spearman rank correlation between biovolume of shredders and total benthic organisms, respectively, against benthic coarse detritus for each site during each season and for each site during all dates combined. Shredders showed significant ($p < 0.05$) correlations with coarse detritus for all cases at site 1 and for all dates combined at sites 2 and 3. Total benthic organisms showed significant ($p < 0.05$) correlations with coarse detritus for all dates combined at site 1 and site 2, and for fall at site 1 and site 4.

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TABLE 6. Shredder biovolume (ml/m^2) against coarse particulate organic matter (AFDW/m^2). Spearman rank correlation coefficients listed. Significance indicated by: NS = not significant ($p > 0.05$), * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$ (cf. table R, table Q, Sharp 1979).

	SPRING (n = 6)	SUMMER (n = 6)	FALL (n = 6)	ALL DATES COMBINED (n = 18)
SITE 1	0.829 *	0.829 *	0.886 *	0.796 ***
SITE 2	0.812 NS	- 0.086 NS	0.771 NS	0.576 **
SITE 3	-0.494 NS	0.395 NS	0.493 NS	0.493 *
SITE 4	0.131 NS	0.655 NS	0.778 NS	0.315 NS

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TABLE 7. Benthic insect biovolume (ml/m^2) against coarse particulate organic matter ($AFDW/m^2$). Spearman rank correlation coefficients listed. Significance indicated by: NS = not significant ($p > 0.05$), * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$ (cf. table R, table Q, Sharp 1979).

	SPRING (n = 6)	SUMMER (n = 6)	FALL (n = 6)	ALL DATES COMBINED (n = 18)
SITE 1	0.771 NS	0.657 NS	0.886 *	0.756 ***
SITE 2	0.771 NS	- 0.314 NS	0.371 NS	0.471 *
SITE 3	-0.600 NS	-0.088 NS	0.314 NS	0.194 NS
SITE 4	0.486 NS	0.429 NS	0.886 *	0.089 NS

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DISCUSSION

Comparative Community Composition

The richness and composition of the benthic invertebrate fauna found in this study (table 3) resembles communities of other Alaskan streams in the Brooks Range (Slack et al 1979; E.V.S. Consultants,Ltd. 1983) and in the subarctic interior (Howe 1981; Cowan 1983; Cowan and Oswood 1984; Oswood et al 1984). In addition, the numerical density of benthic invertebrates found in this study (figure 8) is in the same range as that of most Alaskan and temperate streams (cf. figure 4, Cowan and Oswood 1984). All of the study sites (except site 1 for numbers, figure 8) showed a summer low in the number and biovolume of total benthic invertebrates. This is in agreement with the general model of seasonal fluctuations found by Hynes (1970) for temperate streams, and found by Cowan and Oswood (1984) in a subarctic stream.

Table 8 shows the percent composition of benthic insect orders found at sites in this study and other studies of streams in arctic, subarctic, and temperate regions. The temperate stream listed in table 8 has a fauna typical for Rocky Mountain streams (cf. 11 Rocky Mountain streams listed in table 3, Andrews and Minshall 1979). The high latitude streams share some remarkably similar characteristics. Compared to structurally similar temperate streams, Diptera and Plecoptera are overrepresented while Ephemeroptera are underrepresented. Many major taxa (Trichoptera, Coleoptera, Megaloptera, Hemiptera) are in low abundance or absent in high

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Table 8. Percent composition (number / m^2) of major benthic insect orders in arctic, subarctic, and temperate areas.

Location /Reference	Stream Order	% Composition (Based on Number / m^2) Plecoptera	Ephemeroptera	Coleoptera	Trichoptera	Diptera
ARCTIC:						
Dietrich River, Ak. (site D1) Slack et al. (1979)	1st	2.4	0	0	0	97.6
Dietrich River, Ak. (site D5) Slack et al. (1979)	5th	23.8	7.1	0.4	1.7	66.9
Red Dog Cr., Ak. (site 180), EVS Consultants (1983)	1st	34.1	13.4	trace	0	52.5
SUBARCTIC:						
Stampede Cr., Ak. (site 1), this study	1st	49.3	1.6	0	trace	49.0
Stampede Cr., Ak. (site 2), this study	2nd	54.1	0.3	0	trace	45.5
Stampede Cr., Ak. (site 3), this study	2nd	24.6	11.0	0	0	64.4
Clearwater Fork, Ak. (site 4), this study	5th	23.6	27.2	0	0.2	49.0
Little Poker Cr., Ak. Oswood, et al. (1984)	1st	17.3	15.9	0	2.0	64.8
Monument Cr., Ak. Cowan (1983)	2nd	6.4	29.3	0	0.4	63.9
TEMPERATE:						
Mink Cr., Idaho Minshall (1981)	3rd	9.0	47.6	18.3	10.4	14.7

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latitude streams but are common components of the stream benthos in temperate areas.

Longitudinal Patterns

The River Continuum Concept (Vannote et al 1980) predicts that many factors (stream morphology, current velocity, substrate composition, temperature, and detrital-based versus primary producer-based energy inputs) interact to influence the availability of food to invertebrate consumers, thereby regulating the distribution patterns of functional feeding groups. Specifically, as outlined by Minshall et al (1983), shredders are expected to be codominant with collector/gatherers in the headwaters and to diminish rapidly in importance downstream as the detrital base shifts from mainly coarse particles to fine particles. Collector/gatherers are expected to increase in importance downstream becoming the predominant macroinvertebrate component in large rivers. The results (figure 11) clearly show this pattern when site 1 is compared to site 4. The shift from codominance of shredders and collector/gatherers to dominance of collector/gatherers occurs between site 3 (2nd order) and site 4 (5th order). These results would be even more pronounced if Chironomidae were added to the collector/gatherers to which they may very well belong. Grazers are expected to increase in importance downstream as primary productivity increases with decreased canopy cover and increased light penetration (reaching a maximum in mid-sized rivers). Results for grazers (figure 11), however, do not support this pattern. Grazers are slightly

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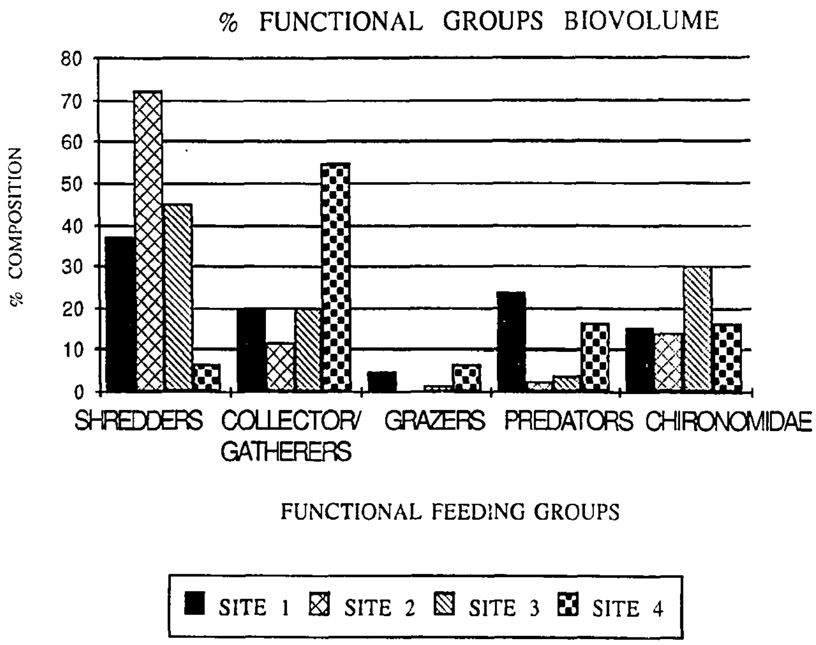

Figure 11. Percent composition by biovolume of major functional groups at each site (average for all dates).

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higher in importance at site 4 compared to site 1, but they are essentially absent at site 2 and greatly reduced at site 3. Filter-feeders should become more abundant downstream as fine detritus and seston increases. As is common in interior Alaskan streams, Simuliidae were the only filter-feeders found. Prosimulium increases in abundance with increasing stream size (figure 6). Predators are not expected to vary in relative dominance with stream size. In this study they exhibit that pattern if site 1 is compared to site 4 (figure 11), but at site 2 they are essentially absent and at site 3 they are greatly reduced.

The River Continuum Concept was developed to help explain conditions found in unperturbed systems and has been shown to be generally predictive regarding changes in relative abundance of functional groups from headwater streams to large rivers in many studies (Naiman and Sedell 1980; Hawkins and Sedell 1981; Culp and Davies 1982; Minshall et al 1983). The present study, while spanning a large range of stream sizes (1st-5th order), only covers a short distance (3 km). However, Townsend and Hildrew (1984) also discerned an orderly pattern of change in macroinvertebrate community structure along a short length of a headwater stream. The results of the present study show that the relative abundance of some functional groups (shredders, collector/gatherers, filter-feeders) change along this stream to river system as predicted by the River Continuum Concept while others (grazers, predators) are distinctly anomalous in pattern at sites 2 and 3. The change in relative abundance of functional groups between site 1 and site 4 matches the predictions of the River Continuum Concept. The effects

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of mining and local geolithic conditions (i.e. high levels of heavy metals) undoubtedly confound predictions of the River Continuum Concept.

The distribution of coarse detritus in this stream system (figure 10) follows the pattern predicted by the River Continuum Concept (Vannote et al 1980) of decreasing importance with increasing stream size. The anomalous summer peak at site 4 is probably due to heavy July rains that also occurred in other Alaskan streams and concentrated high amounts of detritus for short periods of time (Cowan and Oswood 1984). Site 1 had the most detritus during all seasons. The average benthic coarse detritus at site 1 (20.81 gm AFDW/m^2, appendix A) is very similar to the average (22.6 gm AFDW/m^2) of benthic coarse detritus found by Short and Ward (1981) in a high altitude Colorado stream. The amount of coarse benthic detritus found at each of the sites is similar in value to another interior Alaskan stream but much less than the amount typically found in temperate streams (Cowan and Oswood 1983). Shredder biovolume was positively correlated with amount of coarse detritus for all cases at site 1 (table 6). The relationship between shredders and coarse detritus would be expected to be the strongest at that site. Site 4, where the relationship would be expected to be the weakest, has no cases of positive correlation between shredders and coarse detritus. Total benthic insect biovolume showed no pattern of correlation with amount of coarse detritus (table 7). These results do not support Egglishaw's (1964) hypothesis that the distribution of detritus on the streambed influences the distribution of benthic invertebrates.

Predator biovolume was not correlated with prey biovolume (total benthic insects excluding predators) for all cases (table 5). Many other

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benthic studies (Fahy 1975; Hawkins and Sedell 1981; Hawkins et al 1982) have found positive correlations between abundances of predators and prey.

A shift from heterotrophic (production < respiration) to autotrophic (production > respiration) stream metabolism is expected to be primarily dependent upon the degree of shading from the riparian canopy (Cummins 1974). In temperate forests the transition is approximately at 3rd order streams, while at higher elevations and latitudes the transition to autotrophy is thought to occur as early as 1st order streams (Vannote et al 1980). The ratio of shredders or collector/gatherers to scrapers is indicative of the importance of coarse detritus or fine detritus to periphyton as nutritional resources (Cummins 1974). Hawkins et al (1982) found that the biomass of scrapers increased as the biomass of aufwuchs (periphytic primary producers) increased. Baetis populations are known to respond directly to changes in autochthonous production (Wallace and Gurtz 1985). Site 1 had a closed riparian canopy and narrow stream channel while sites 2 and 3 were wider and open to much more light penetration. I expected to see much more indirect evidence (increased abundance of grazers) of a shift to autotrophic metabolism at sites 2 and 3. The biovolume of grazers in this study (figure 4) was greatest (seasonal average) at site 1 (due to the biovolume abundance of Gymnopais) followed by site 4 (due to the biovolume abundance of Baetis). Grazers were in very low abundance at site 3 and were essentially absent at site 2. Pseudocleon and Glossosomatidae, the other grazer taxa, occur only at site 4. Some studies (Kondratieff et al 1984; Dudgeon 1984) have shown grazers to be excluded at polluted sites.

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Site 3 has the lowest abundance of benthic insects (figure 8) and has a high percent composition of oligochaetes during every season (figure 7). Both sites 2 and 3 were below road crossings and possibly have been affected by disturbance associated with the road crossings. Disturbance can lead to a decrease in diversity and abundance of benthic invertebrates from loss of habitat diversity and increased sediment load, and a decrease in periphyton from scouring and light limitation (Oswood et al 1984). Wagener (1984) found a reduction in benthic invertebrate abundance in placer mined (high turbidity), small order, interior Alaskan streams. But, he also found that disturbed sites showed a higher proportion of collector/gatherers. Both sites 2 and 3 have proportionately more shredders than other groups (figure 11).

Effects of Heavy Metals

Toxicity from heavy metals is dependent on many factors including: water quality conditions, sediment characteristics, properties of the particular metal and presence of other metals, and the ecology of the particular organism and community (Forstner and Wittman 1981; Roline and Boehmke 1981). It is therefore difficult to determine or predict the precise concentrations of heavy metals that would be toxic to aquatic life. It is also difficult to measure the concentrations of heavy metals to which organisms are actually exposed in the field. In this study the data on heavy metal concentrations for the study sites (West 1982; West and Deschu 1984) are of amounts suspended in the water column. Heavy metals desorb

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from sediments into interstitial water and influence invertebrate survival (Moore and Ramamoorthy 1984). Benthic organisms are most likely to be directly affected by sediment metal concentrations and not the concentration of metals dissolved in the water (Laws 1981). Consequently, heavy metal concentrations measured by water samples can give a highly misleading underestimate of heavy metal contamination (Laws 1981). Conversely, Roline and Boehmke (1981) found several benthic invertebrate taxa in water with dissolved heavy metal concentrations in excess of documented toxic levels.

The response of a community to heavy metal contamination is quite variable and dependent on many components (microbiota, algae, invertebrates, fish) which may all react and interact differently. There is surprisingly little difference in numbers or biovolume of benthic insects (figure 8) between site 1 with generally the least heavy metal contamination and site 2 with the most. Site 1 serves as a control site for comparing the effects of mining related heavy metal contamination on the abundance of benthic invertebrates. However, site 1 has naturally occurring high concentrations of many heavy metals (especially selenium). The best possible study on the effects of mining would be a comparison of the same study site before mining began and then afterwards. Predictions of the River Continuum Concept must be taken into account when comparing the benthic community between upstream and downstream sites.

Comparisons with other interior Alaskan sites (without elevated levels of heavy metals) must be made in order to look at the effects of heavy metals on the abundance of benthic invertebrates. As already

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described (table 3 and 8), the abundance and community composition of benthic invertebrates found in this study resembles that of other interior Alaskan streams. West (1982) concluded, in studying the same watershed, that due to the ameliorating effects of high pH, hard water, low water temperatures, and high dissolved oxygen, the Kantishna Hills stream biota may have a relatively high tolerance to high levels of heavy metals.

A characteristic feature of toxic polluted stream communities is the differential elimination of taxonomic groups (Hynes 1963). In this study Ameletus (figure 3), Baetis and Gymnopais (figure 4), and Chloroperlidae (figure 5) showed a sharp decrease in abundance at site 2. Ameletus and Gymnopais could perhaps be limited by factors (e.g. temperature, current velocity, substrate size, etc.) other than heavy metal contamination. Baetis was found at all sites except the site directly below the mine. Chloroperlidae were essentially absent at the two sites below the mine while abundant at the sites above and far below the mine. Because of the various levels of taxonomic identification (from class to genus), the total number of taxa at each site can not be meaningfully compared (i.e. species richness, diversity indices,etc., can not be used). Further delineation of taxa would probably increase the number of different organisms with sharply restricted distributions (e.g. Chloroperlidae populations are probably composed of at least two species with disjunct distributions).

Nemoura showed a sharp increase in abundance at site 2 which, due to its great numbers, caused the shredders to show maximum density at site 2. Standing crop of coarse detritus is much lower at site 2 compared to site 1 (figure 10) but perhaps Nemoura is more tolerant of heavy metals and is

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released from competition with the other nemourid shredders (Zapada, Podmosta), which drop sharply in abundance between site 1 and site 2. Alternatively, perhaps the sharp decrease in predators at site 2 (figure 5) led to the increased abundance of Nemoura.

Ephemeropterans as a group have been found in several studies (Winner et al 1975; 1980; Burrows and Whitton 1983) to be one of the most sensitive benthic taxa to heavy metal pollution. The data for this study are consistent with this expectation (figure 9); they show ephemeropterans to be the most depressed in abundance at sites 2 and 3 relative to sites 1 and 4. An alternative hypothesis to heavy metal contamination leading to their exclusion is that the ephemeropterans are following a temperature gradient, increasing at site 4 as the temperature increases. This hypothesis is supported by Wiggins and Mackay (1978) who state that ephemeropterans occur most often in warm lotic environments. Another explanation might be that because many ephemeropterans are grazers (Wiggins and Mackay 1978) and as essentially no grazers occur at site 2 and few at site 3 (figure 4), presumably due to a lack of primary producers, their distribution is limited to sites 1 and 4.

Chironomidae and Oligochaeta are ubiquitous and cosmopolitan inhabitants of sediments over a wide range of environmental conditions. Chironomidae are often dominant components of benthic invertebrate communities in heavy metal contaminated streams (Winner et al 1975; 1980; Sheehan 1980). Oligochaeta have been found to be tolerant of heavy metals and good biotic indicators of heavy metal contamination in some studies (Chapman et al 1980; Winner et al 1980), whereas in others to be

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intolerant of heavy metals and good biotic indicators of unpolluted waters (Hynes 1963; E.V.S. Consultants Ltd. 1983; Chapman and Brinkhurst 1984). In this study, Chironomidae are neither a dominant benthic group (figure 11), nor concentrated at the most contaminated sites (figure 6). Oligochaeta, in this study, occur at all sites with greatest abundance at site 1 and very low abundance at site 4; they are often major components of the benthic fauna, but show no clear longitudinal pattern of dominance (figure 7). Invertebrates are a diverse group and it is difficult to predict a consistent response to heavy metals, so the presence, absence or relative abundance of certain invertebrate taxa are not good indications of water quality for chemically polluted systems (Slooff 1983; Moore and Ramamoorthy 1984).

Several studies have shown the differential elimination of functional feeding groups as a result of heavy metal contamination (Hendrix et al 1982; Kondratieff et al 1984; Rabeni et al 1985). In this study, grazers and predators (figure 11) are virtually absent from site 2 and in very low proportion at site 3 compared to sites 1 and 4. In fact, grazers are in very low absolute and relative abundance at all the sites. Perhaps grazers are limited by the scarcity of primary producers which are themselves depressed by heavy metal contamination. Other structurally similar streams (Upper Eldorado Cr.) in the same region (Kantishna Hills) support abundant mosses, and periphyton (Meyer and Kavanagh 1983). No mosses or periphyton were observed at any of the study sites. Gut analyses found no filamentous algae in any guts and only trace amounts of diatoms in any guts from organisms at site 2 (Appendix D). Jones (1958) had similar results with the availability of primary producers (as a food source for grazers)

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limited in a heavy metal contaminated stream section. Sheehan (1984a) states that heavy metal-induced depression of productivity certainly occurs and may persist in polluted aquatic systems. It remains to be seen if the lack of grazers accurately reflects the lack of primary producers.

An alternative hypothesis to heavy metal-induced depression of primary productivity is that other environmental factors (e.g. long ice cover, ice scouring of the stream bed, and low water temperatures) are limiting primary producers. Van Nieuwenhuyse (1983) and Anderson (1984) suggested that algal communities in interior Alaskan streams exhibit specific adaptations to prevailing conditions of low light and low temperature. However, they also found these algal stream communities to have the lowest standing crop reported in the literature. Naiman (1983) found the role of periphyton to be minor in streams of undisturbed boreal forests. Thus, primary producers may be depressed by heavy metal contamination at this particular site or may be generally limited by environmental conditions of high latitude streams. A useful control site for the comparison of relative and absolute abundance of grazers would be another structurally similar watershed, in the same area, which does not have naturally occurring high levels of heavy metals and has not been disturbed. As of yet, there have been no global studies of productivity processes in a high latitude lotic ecosystem (Harper 1981). The relative importance of primary production in northern streams remains to be elucidated.

Predators are in very low relative and absolute abundance at sites 2 and 3 (figures 5 and 11) but do not appear to be limited by prey abundance at

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these sites (figure 8). Sheehan (1980) found that the proportion of predators was the most predictive parameter along a copper polluted stream gradient, with percent abundance of predators dropping radically in response to copper pollution. Odum (1985) states that food chains shorten because of reduced energy flow at higher trophic levels and/or greater sensitivity of predators to stress. The reasons for this are not understood, although Odum (1985) offers two explanations: 1) small organisms outcompete large organisms under toxic stress (and enrichment), 2) large organisms are subject to bioaccumulation of toxins, have vulnerable life history stages, or are otherwise more sensitive to disturbance than small organisms. However, bioaccumulation does not appear to occur with most (mercury is a notable exception) heavy metal contamination (Forstner and Wittmann 1981; Burrows and Whitton 1983; Selby et al 1985), unlike the case of organic pesticides (e.g. DDT) where the highest concentrations of the pollutant occur in the highest trophic levels (Forstner and Wittman 1981). In fact often the most bioaccumulation occurs in lower trophic levels (Funk et al 1975; Hutchinson et al 1976.), this however, may be a result of an adsorption phenomenon which has no biological significance (Moriarty 1983).

Many studies have found that pollution in general brings about a simplification of ecosystem structure (Woodwell 1970; Bourdeau and Treshow 1978; Odum 1985; Rapport et al 1985). The particular causal mechanisms involved are still a mystery. Cummins and Klug (1979) predict that benthic invertebrate generalists will perform better (i.e. grow and reproduce more) than specialists under disturbed or altered stream conditions in which a particular food resource is reduced or eliminated.

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Dudgeon (1984) found evidence for this prediction in an organically polluted stream in which generalist benthic invertebrates increased as other functional groups were excluded. Perhaps high heavy metal concentrations limit primary production (and indirectly, grazers) and act as a reset mechanism causing the overall river continuum response to be shifted toward the headwaters (i.e. heterotrophically structured communities). Some investigations (Hendrix et al 1982; Kondratieff et al 1984; Rabeni et al 1985) show evidence of benthic invertebrate communities responding to pollution stress with shifts in trophic structure from predominantly autotrophic to heterotrophic. Howmiller and Scott (1977) caution, however, that since macroinvertebrate communities act as integrators, care must be exercised in attempting to attribute changes in their structure to particular cause.

This study suggests that chronic heavy metal contamination of this stream system may have affected benthic insect taxonomic and functional groups differentially. However, there is no conclusive evidence that mining has affected or not affected the benthic invertebrate community.

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CONCLUSIONS

1) Four contiguous study sites were investigated along a short (4.6 km) stream section ranging from a narrow, shaded, 1st order headwater stream to a wide, open-canopied, 5th order river. One site was above an antimony mine (active 1916 - 1970) and three sites were below the mine at various distances. The headwater stream was characterized by very low water temperature and relatively high benthic storage of coarse detritus. Water temperature increased and detrital storage decreased downstream.

2) Major taxa included stoneflies (Nemouridae:*Nemoura*, *Podmosta*, *Zapada*; Chloroperlidae, Perlodidae, Capniidae, Taeniopterygidae), mayflies (Siphlonuridae:*Ameletus*; Heptageniidae:*Cinygmula*, *Epeorus*; Baetidae:*Baetis*) and dipterans (Tipulidae:*Tipula*, *Dicranota*; Simuliidae:*Prosimulium*, *Gymnopais*; Chironomidae, Empididae). Most taxa showed significant, longitudinal distribution patterns along the river system.

3) Taxonomic diversity of stream insects was low compared to temperate streams but similar to other interior Alaskan stream systems. Compared to structurally similar temperate streams, Plecoptera and Diptera were overrepresented while Ephemeroptera were underrepresented. Trichoptera were nearly absent and no Coleoptera, Megaloptera or Hemiptera were found.

4) Abundance (number and biovolume) of total benthic insects was not much different between the site above the mine and the site immediately below,

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but did decline at the lower two sites. Benthic insect numerical abundance at all sites was similar to other interior Alaskan streams and temperate streams.

5) Despite high concentrations of many heavy metals in the water (in excess of various water quality standards) the benthic invertebrate community did not appear to be severely impacted. Benthic invertebrate community composition is similar to other interior Alaskan streams.

6) Standing crop of coarse detritus (> 1mm) was relatively high at the 1st order site above the mine (similar in value to a high altitude temperate stream), and declined progressively at downstream sites (all of which had values comparable to another interior Alaskan stream but much less than values from structurally similar temperate streams). Abundance of shredders was positively correlated with abundance of coarse detritus at the 1st order, headwater site.

7) Distinct longitudinal changes in functional group composition of benthic insects occurred between the small headwater stream sites and the downstream river site. Upstream sections were dominated by shredders which feed upon coarse detritus. Downstream, as availability of coarse detritus decreased, shredders declined in importance. Conversely, collector/gatherers, which feed upon fine detritus, increased in relative abundance downstream. Filter-feeders increased in abundance downstream. Between site 1 (the control site above the mine) and site 4 (the farthest

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downstream site), grazers increased in relative abundance and predators maintained the same relative abundance. These results support predictions of the River Continuum Concept.

8) At the two intermediate sites below the antimony mine, grazers and predators show anomalous patterns (inconsistent with predictions of the River Continuum Concept) of relative abundance. One hypothesis is that heavy metal induced depression of primary producers (and associated grazer food webs) is occurring. Alternatively, perhaps primary production is naturally low in high latitude stream systems and the longitudinal pattern observed is simply a sampling artifact. Abundance of predators was not correlated with abundance of prey (all benthic insect taxa which are not predators).

9) Chronic heavy metal contamination of this stream system may have affected benthic insect taxonomic and functional groups differentially. Chloroperlidae were essentially absent at the two sites below the mine while abundant at the sites above and far below the mine. Baetis was found at all sites except the site directly below the mine. Grazers and predators were essentially absent at the site directly below the mine and in very low abundance at the next site downstream. However, there is no conclusive evidence that mining affected or did not affect the distribution of benthic invertebrates.

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LITERATURE CITED

Anderson, P.R. 1984. Seasonal changes of attached algae in two Alaskan subarctic streams. M.S. Thesis. University of Alaska, Fairbanks, Ak. 113pp.

Andrews, D.A. and G.W. Minshall. 1979. Distribution of benthic invertebrates in the Lost Streams of Idaho. American Midland Naturalist 102:140-148.

Bourdeau, P. and M. Treshow. 1978. Ecosystem response to pollution. Pages 313-330 in G.C. Butler (ed.). Principles of Ecotoxicology, SCOPE 12. John Wiley and Sons, New York.

Brown, B.N. and M.W. Oswood. 1985. Community structure and longitudinal patterns of benthic invertebrates in a heavy metal contaminated Alaskan river system. Pages 53-63 in L.P. Dwight (Chairman). Resolving Alaska's Water Resources Conflicts. Proceedings. Alaska Section, American Water Resources Association. Institute of Water Resources/Engineering Experiment Station, University of Alaska-Fairbanks. Report IWR-108. 212pp.

Bundtzen, T.K. 1978. A history of mining in the Kantishna Hills. The Alaska Journal: 151-161.

Bundtzen, T.K. 1981. Geology and mineral deposits of the Kantishna Hills, Mt. Mckinley Quadrangle, Alaska. M.S. Thesis. University of Alaska, Fairbanks, Ak. 238pp.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Burrows, I.G. and B.A. Whitton. 1983. Heavy metals in water, sediments and invertebrates from a metal-contaminated river free of organic pollution. Hydrobiologia 106:263-273.

Cairns Jr.,J. 1983. Are single species toxicity tests alone adequate for estimating environmental hazard? Hydrobiologia 100:47-57.

Chapman, P.M., L.M. Churchland, P.A. Thomson, and E. Michnowsky. 1980. Heavy metal studies with oligochaetes. Pgs. 477-502 in R.O.Brinkhurst and D.G. Cook (eds.). Aquatic oligochaete biology. Plenum Press, New York.

Chapman, P.M. and R.O. Brinkhurst. 1984. Lethal and sublethal tolerances of aquatic oligochaetes with reference to their use as a biotic index of pollution. Hydrobioiogia 115: 139-144.

Coffman,W.P. and L.C. Ferrington Jr. 1984. Chironomidae. Pages 551-625 in R.W. Merritt, K.W. Cummins (eds.). An introduction to the aquatic insects of North America, second edition. Kendall/Hunt Publishing Co. Dubuque, Iowa.

Cowan, C.A. 1983. Phenology of benthic detritus input, storage and processing in an Alaskan subarctic stream. M.S. Thesis. University of Alaska, Fairbanks, Ak. 98pp.

Cowan, C.A. and M.W. Oswood. 1983. Input and storage of benthic detritus in an Alaskan subarctic stream. Polar Biology 2:35-40.

Cowan, C.A., M.W. Oswood, C.A.Buttimore and P.W.Flanagan. 1983. Processing and macroinvertebrate colonization of detritus in an Alaskan subarctic stream. Holarctic Ecology 6:340-348.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Cowan,C.A., and M.W. Oswood. 1984. Spatial and seasonal associations of benthic macroinvertebrates and detritus in an Alaskan subarctic stream. Polar Biology 3:211-215.

Culp, J.M. and R.W. Davies. 1982. Analysis of longitudinal zonation and the River Continuum Concept in the Oldman-South Saskatchewan River System. Canadian Journal of Fisheries and Aquatic Science 39:1258-1265.

Cummins, K.W. 1974. Structure and function of stream ecosystems. BioScience 24:631-41.

Cummins, K.W. and M.J. Klug. 1979. Feeding ecology of stream invertebrates. Annual Review of Ecology and Systematics 10:147-172.

Dudgeon, D. 1984. Longitudinal and temporal changes in functional organization of macroinvertebrate communities in the Lam Tsuen River, Hong Kong. Hydrobiologia 111: 207-217.

Egglishaw, H.J. 1964. The distributional relationship between the bottom fauna and plant detritus in streams. Journal of Animal Ecology 33:463-476.

E.V.S. Consultants Ltd. 1983. Toxicological, biophysical, and chemical assessment of Red Dog Creek, Delong Mountains, Ak. Prepared for Alaska Department of Environmental Conservation, Juneau, by G. Vigers, J. Barret, R. Hoffman, J. Humphrey, D. Kathman, D. Konasewich, R. Olmsted, and B. Reid. 245pp.

Fahy, E. 1975. Quantitative aspects of the distribution of invertebrates in the benthos of a small stream system in western Ireland. Freshwater Biology 5: 167-182.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Forstner, U. and G.T.W. Wittmann. 1981. Metal pollution in the aquatic environment. Springer-Verlag, New York, N.Y. 486pp.

Funk, W.H., F.W. Rabe, R. Filby and G. Bailey. 1975. An integrated study on the impact of metallic trace element pollution in the Coeur D'Alene-Spokane Rivers and Lake Drainage System. National Technical Information Service PB-256 724, Washington, D.C.

Harper, P.P. 1981. Ecology of streams at high latitudes. Pages 313-318 in M.A. Lock and D.D. Williams (eds.). Perspectives in running water ecology. Plenum Press, New York, N.Y.

Hartung, R. 1973. Biological effects of heavy metal pollutants in water. Pages 161-172 in S.K. Dhar (ed.). Metal ions in biological systems: studies of some biochemical and environmental problems. Plenum Press, New York, N.Y.

Hawkins, C.P. and J.R. Sedell. 1981. Longitudinal and seasonal changes in functional organization of macroinvertebrate communities in four Oregon streams. Ecology 62:387-397.

Hawkins, C.P., M.L.Murphy and N.H. Anderson. 1982. Effects of canopy, substrate composition, and gradient on the structure of macroinvertebrate communities in Cascade Range Streams of Oregon. Ecology 63:1840-1856.

Hendrix, P.F., C.L. Langner and E.P. Odum. 1982. Cadmium in aquatic microcosms: implications for screening the ecological effects of toxic substances. Environmental Management 6:543-553.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Howe, A.L. 1981. Life histories and community structure of Ephemeroptera and Plecoptera in two Alaskan subarctic streams. M.S. Thesis. University of Alaska, Fairbanks, Ak. 108pp.

Howmiller, R.P. and M.A. Scott. 1977. An environmental index based on relative abundance of oligochaete species. Journal Water Pollution Control Federation 49:809-815.

Hunter, C. 1985. This our land. Alaska 51:49-50.

Hutchinson, T.C., A. Fedorenko, J. Fitchko, A. Kuja, J. Vanloon, J. Lichwa. 1976. Movement and compartmentation of nickel and copper in an aquatic ecosystem. Pages 565-585 in J.O. Nriagu (ed.). Proceedings of the 2nd International Symposium on Environmental Biochemistry. Ann Arbor Science, Ann Arbor, MI.

Hynes, H.B.N. 1963. The biology of polluted waters. Liverpool University Press, England. 202pp.

Hynes, H.B.N. 1970. The ecology of running waters. University of Toronto Press, Toronto, Canada. 555pp.

Irons, J.G. 1985. Life histories and community structure of the caddisflies (Trichoptera) of two Alaskan subarctic streams. M.S. Thesis. University of Alaska, Fairbanks, Ak. 185pp.

Jones, J.R.E. 1958. A further study of the zinc-polluted river Ystwyth. Journal of Animal Ecology 27:1-14.

Kondratieff, P.F., R.A. Matthews and A.L. Buikema, Jr. 1984. A stressed stream ecosystem: macroinvertebrate community integrity and microbial trophic response. Hydrobiologia 111:81-91.

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LaPoint, T.W., S.M. Melancon, M.K. Morris. 1984. Relationships among observed metal concentrations, criteria, and benthic community structural responses in 15 streams. Journal of Water Pollution Control 56:1030-1038.

Laws, E.A. 1981. Aquatic pollution. John Wiley and Sons, New York, N.Y. 482pp.

Leland, H.V. and J.S. Kuwabara. 1985. Trace metals. Pages 374-415 in G.M. Rand and S.R. Petrocelli (eds.). Fundamentals of aquatic toxicology. Hemisphere Publishing Co., New York, N.Y.

Merritt, R.W. and K.W. Cummins (eds.). 1984. An introduction to the aquatic insects, second edition. Kendall/Hunt Publishing Company, Dubuque, Iowa. 722pp.

Meyer, S.C. and R.C.Kavanagh. 1983. Fish resources and the effects of mining activities in the Kantishna Hills, Denali National Park, 1982. U.S.Dept. of Interior, National Park Service, Alaska. 150pp.

Minshall, G.W. 1981. Structure and temporal variations of the benthic macroinvertebrate community inhabiting Mink Creek, Idaho, U.S.A., a 3rd Order Rocky Mountain stream. Journal of Freshwater Ecology 1:13-26.

Minshall, G.W., R.C. Peterson, K.W. Cummins, T.L. Bott, J.R. Sedell, C.E. Cushing and R.L. Vannote. 1983. Interbiome comparison of stream ecosystem dynamics. Ecological Monographs 53:1-25.

Minshall, G.W., K.W. Cummins, R.C. Peterson, C.E. Cushing, D.A. Bruns, J.R. Sedell and R.L. Vannote. 1985. Developments in stream ecosystem

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theory. Canadian Journal of Fisheries and Aquatic Science 42:1045-1055.

Moore, J.W. and S. Ramamoorthy. 1984. Heavy metals in natural waters. Springer-Verlag, New York, N.Y. 268pp.

Moriarty, F. 1983. Ecotoxicology. Academic Press, New York, N.Y. 233 pp.

Naiman, R.J. and J.R. Sedell. 1980. Relationships between metabolic parameters and stream order in Oregon. Canadian Journal of Fisheries and Aquatic Science 37: 834-847.

Naiman, R.J. 1983. A geomorphic approach for examining the role of periphyton in large watersheds. Pages 1-20 in R.G. Wetzel (ed.). International workshop on periphyton of freshwater ecosystems. Kluwer, Boston.

Odum, E.P. 1985. Trends expected in stressed ecosystems. Bioscience 35:419-422.

Oswood, M.W., C.W. Slaughter, J.W. Hilgert. 1984. Effects of vegetation removal in an Alaskan subarctic watershed: preimpact benthic invertebrate studies. Pages 183-193 in S.R. Bredthauer (chairman). Alaska's water: a critical resource. Proc. Alaska section, American Water Resources Association. Institute of Water Resources, University of Alaska, Fairbanks. Report IWR 106. 224pp.

Passow, H., A. Rothstein and T.W. Clarkson. 1961. The general pharmacology of heavy metals. Pharmacological Review 13:185-224.

Rabeni, C.F., S.P. Davies and K.E. Gibbs. 1985. Benthic invertebrate response to pollution abatement: structural changes and functional implications. Water Resources Bulletin 21:489-497.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Roline, R.A. and J.R. Boehmke. 1981. Heavy metals pollution of the upper Arkansas River, Colorado and its effects on the distribution of the aquatic macrofauna. Bureau of Reclamation, U.S. Department of the Interior, Denver, Colorado. 50pp.

Selby, D.A., J.M. Ihnat and J.J. Messer. 1985. Effects of subacute cadmium exposure on a hardwater mountain stream microcosm. Water Resources 19:645-655.

Sharp, V.F. 1979. Statistics for the social sciences. Little, Brown & Company, Boston, Mass. 381pp.

Sheehan, P.J. 1980. The ecotoxicology of copper and zinc: studies on a stream macroinvertebrate community. PhD Thesis. University of California, Davis, California.

Sheehan, P.J. 1984a. Functional changes in the ecosystem. Pages 101-146 in P.J. Sheehan, D.R. Miller, G.C. Butler and P. Bourdeau (eds.). Effects of pollutants at the ecosystem level. John Wiley and Sons, New York, N.Y.

Sheehan, P.J. 1984b. Effects on community and ecosystem structure and dynamics. Pages 51-99 in P.J. Sheehan, D.R. Miller, G.C. Butler and P. Bourdeau (eds.). Effects of pollutants at the ecosystem level. John Wiley and Sons, New York, N.Y.

Sheehan, P.J. and R.W. Winner. 1984. Comparison of gradient studies in heavy metal polluted streams. Pages 255-272 in P.J. Sheehan, D.R. Miller, G.C. Butler and P. Bourdeau (eds.). Effects of pollutants at the ecosystem level. John Wiley and Sons, New York, N.Y.

Short, R.A. and J.V. Ward. 1981. Benthic detritus dynamics in a mountain stream. Holarctic Ecology 4:32-35.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Slack, K.V., J.W. Nauman and L.J. Tilley. 1979. Benthic invertebrates in a north-flowing stream and a south-flowing stream, Brooks Range, Alaska Water Resources Bulletin 15:108-135.

Slooff, W. 1983. Benthic macroinvertebrates and water quality assessment: some toxicological considerations. Aquatic Toxicology 4: 72-82.

Statzner, B. and B. Higler. 1985. Questions and comments on the River Continuum Concept. Canadian Journal of Fisheries and Aquatic Science 42:1038-1044.

Townsend, C.R. and A.G. Hildrew. 1984. Longitudinal pattern in detritivore communities of acid streams: a consideration of alternative hypotheses. International Association of Theoretical and Applied Limnology 22:1953-1958.

U.S. Department of the Interior, National Park Service. 1984. Final Environmental Impact Statement for the Kantishna Hills/Dunkle Mine study report: Denali National Park and Preserve. Anchorage, Ak. 616pp.

Van Niewenhuyse, E.E. 1983. Effects of placer mining on the primary productivity of interior Alaskan streams. M.S. Thesis. University of Alaska, Fairbanks, Ak. 120pp.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell and C.E. Cushing. 1980. The River Continuum Concept. Canadian Journal of Fisheries and Aquatic Science 37:130-137.

Wagener, S.M. 1984. Effects of gold placer mining on stream macroinvertebrates of interior Alaska. M.S. Thesis. University of Alaska, Fairbanks, Ak. 99pp.

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Wallace, J.B. and M.E. Gurtz. 1985. Response of baetis mayflies (Ephemeroptera) to catchment logging. American Midland Naturalist 115: 25-41.

West, R.L. 1982. Kantishna Hills heavy metals investigation. U.S. Fish and Wildlife Service, Fairbanks, Ak. 34pp.

West, R.L. and N.A. Deschu. 1984. Kantishna Hills heavy metals investigations Denali National Park, 1983. U.S. Fish and Wildlife Service, Fairbanks, Ak. 42pp.

Wiggins, G.B. and R.J. Mackay. 1978. Some relationships between systematics and trophic ecology in nearctic aquatic insects, with special reference to Trichoptera. Ecology 59:1211-1220.

Winner, R.W., J.S. VanDyke, N.Caris and M.P. Farrel. 1975. Response of the macroinvertebrate fauna to a copper gradient in an experimentally-polluted stream. International Association of Theoretical and Applied Limnology 19:2121-2127.

Winner, R.W., M.W. Boesel and M.P. Farrell. 1980. Insect community structure as an index of heavy-metal pollution in lotic ecosystems. Canadian Journal of Fisheries and Aquatic Science 37:647-655.

Winterbourne, M.J., J.S. Rounick and B. Cowie. 1981. Are New Zealand stream ecosystems really different? New Zealand Journal of Marine and Freshwater Research 15:321-328.

Woodwell, G.M. 1970. Effects of pollution on the structure and physiology of ecosystems. Science 168:429-433.

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APPENDIX A

Sample number, location, date, amount of coarse particulate organic matter (> 1 mm) detritus, and zone type.

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SAMPLE	LOCATION	DATE	CPOM	ZONE
•1	SITE 1	25 JUNE 1981	.387 gm	E
•2	SITE 1	25 JUNE 1981	3.701gm	E
•3	SITE 1	25 JUNE 1981	1.044gm	E
•4	SITE 1	25 JUNE 1981	.779gm	E
•5	SITE 1	25 JUNE 1981	1.112gm	D & E
•6	SITE 1	25 JUNE 1981	.714gm	D
•7	SITE 2	25 JUNE 1981	.408gm	E
•8	SITE 2	25 JUNE 1981	.322gm	D & E
•9	SITE 2	25 JUNE 1981	3.835gm	E
•10	SITE 2	25 JUNE 1981	1.402gm	D & E
•11	SITE 2	25 JUNE 1981	.150gm	E
•12	SITE 2	25 JUNE 1981	.105gm	E
•13	SITE 3	25 JUNE 1981	.229gm	D
•14	SITE 3	25 JUNE 1981	.227gm	E
•15	SITE 3	25 JUNE 1981	.116gm	E
•16	SITE 3	25 JUNE 1981	.233gm	D & E
•17	SITE 3	25 JUNE 1981	.136gm	D & E
•18	SITE 3	25 JUNE 1981	.375gm	D & E
•19	SITE 4	26 JUNE 1981	.188gm	E
•20	SITE 4	26 JUNE 1981	.112gm	E
•21	SITE 4	26 JUNE 1981	.516gm	E
•22	SITE 4	26 JUNE 1981	.116gm	E
•23	SITE 4	26 JUNE 1981	.229gm	E
•24	SITE 4	26 JUNE 1981	.669gm	E
•25	SITE 1	25 JULY 1981	14.998gm	D & E
•26	SITE 1	25 JULY 1981	.810gm	E
•27	SITE 1	25 JULY 1981	.171gm	D
•28	SITE 1	25 JULY 1981	1.537gm	E
•29	SITE 1	25 JULY 1981	1.589gm	E
•30	SITE 1	25 JULY 1981	.957gm	E
•31	SITE 2	27 JULY 1981	.150gm	E
•32	SITE 2	27 JULY 1981	.599gm	E
•33	SITE 2	27 JULY 1981	.421gm	D & E
•34	SITE 2	27 JULY 1981	.308gm	E
•35	SITE 2	27 JULY 1981	.921gm	E
•36	SITE 2	27 JULY 1981	.914gm	D & E
•37	SITE 3	26 JULY 1981	.373gm	E
•38	SITE 3	26 JULY 1981	.307gm	E
•39	SITE 3	26 JULY 1981	.332gm	E
•40	SITE 3	26 JULY 1981	.379gm	E

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SAMPLE	LOCATION	DATE	CPOM	ZONE
•41	SITE 3	26 JULY 1981	.891gm	E
•42	SITE 3	26 JULY 1981	.808gm	E
•43	SITE 4	26 JULY 1981	.108gm	E
•44	SITE 4	26 JULY 1981	1.454gm	E
•45	SITE 4	26 JULY 1981	7.014gm	D & E
•46	SITE 4	26 JULY 1981	.082gm	E
•47	SITE 4	26 JULY 1981	3.013gm	E
•48	SITE 4	26 JULY 1981	3.188gm	E
•49	SITE 1	28 AUGUST 1981	.850gm	D & E
•50	SITE 1	28 AUGUST 1981	2.342gm	D & E
•51	SITE 1	28 AUGUST 1981	4.426gm	E
•52	SITE 1	28 AUGUST 1981	.602gm	E
•53	SITE 1	28 AUGUST 1981	.408gm	E
•54	SITE 1	28 AUGUST 1981	1.031gm	E
•55	SITE 2	29 AUGUST 1981	.735gm	E
•56	SITE 2	29 AUGUST 1981	.347gm	E
•57	SITE 2	29 AUGUST 1981	.487gm	D & E
•58	SITE 2	29 AUGUST 1981	.538gm	D & E
•59	SITE 2	29 AUGUST 1981	2.213gm	D
•60	SITE 2	29 AUGUST 1981	2.275gm	E
•61	SITE 3	29 AUGUST 1981	.230gm	E
•62	SITE 3	29 AUGUST 1981	.514gm	E
•63	SITE 3	29 AUGUST 1981	.758gm	E
•64	SITE 3	29 AUGUST 1981	1.193gm	D & E
•65	SITE 3	29 AUGUST 1981	1.352gm	D & E
•66	SITE 3	29 AUGUST 1981	.973gm	E
•67	SITE 4	28 AUGUST 1981	.031gm	E
•68	SITE 4	28 AUGUST 1981	.038gm	E
•69	SITE 4	28 AUGUST 1981	.023gm	D & E
•70	SITE 4	28 AUGUST 1981	.088gm	E
•71	SITE 4	28 AUGUST 1981	.135gm	D & E
•72	SITE 4	28 AUGUST 1981	1.219gm	E

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APPENDIX B

Number of organisms of each taxon found in each sample (0.1 m^2). Site information for each sample number is given in appendix A.

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TAXA	S 1	S 2	S 3	S 4	S 5	S 6	S 7	S 8
NEMOURA	2	3	1	2	4		83	24
PODMOSTA	14	14	28	30	33	39	14	10
ZAPADA		1			2			
CHLOROPERLIDAE		9	9	7	7	4		
ALLOPERLA								
PERLODIDAE					1			
ISOPERLA								
CAPNIIDAE	4	6	15	19	51	21	45	6
TAENIOPTERYGIDAE								
BAETIDAE								
BAETIS								
PSEUDOCLEON								
EPHEMERELLA								
SERRATELLA								
HEPTAGENIIDAE								
CINYGMULA			2	1				
EPEORUS								
AMELETUS	1	14	9	6	3	5		
CHIRONOMIDAE	40	277	75	166	157	182	153	92
CHIRONOMIDAE (PUPAE)								
GYMNOPAIS	2							
PROSIMULIUM								
SIMULIIDAE (PUPAE)								
TIPULIDAE					1			
TIPULA		2			4			
DICRANOTA	1	29	4	4	2	2	1	
ORMOSIA								
GONOMYODES		2						
EMPIDIDAE							5	
CERATOPOGONIDAE								
PSYCHODIDAE								
MUSCIDAE								
DIXIDAE								
LIMNEPHILIDAE								
GLOSSOMATIDAE								
COLLEMBOLA	1		3	4		20	1	2
OLIGOCHAETA		7	32		41	4		4
NEMATODA	2			4	1		1	
PLATYHELMINTHES								
HYDRACARINA					3	1	1	1
COPEPODA		2	1	2	2			57
CLADOCERA								
UNID. PLECOPTERA								
UNID. EPHEMEROPTERA		1						
UNID. DIPTERA								

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TAXA	S 9	S 10	S 11	S 12	S 13	S 14	S 15	S 16
NEMOURA	183	57	11	81		6	9	1
PODMOSTA	36	5	2	5				
ZAPADA	1							
CHLOROPERLIDAE						1		
ALLOPERLA								
PERLODIDAE								1
ISOPERLA								
CAPNIIDAE	43	55	1	38	2	35	13	11
TAENIOPTERYGIDAE								
BAETIDAE								
BAETIS								
PSEUDOCLEON								
EPHEMERELLA								
SERRATELLA								
HEPTAGENIIDAE								
CINYGMULA	2							
EPEORUS								
AMELETUS	1	1	1					
CHIRONOMIDAE	269	134	43	190	76	86	156	26
CHIRONOMIDAE (PUPAE)								
GYMNOPAIS			1	3				
PROSIMULIUM	3			8		12	6	1
SIMULIIDAE (PUPAE)								
TIPULIDAE								
TIPULA	2	2						
DICRANOTA								
ORMOSIA								
GONOMYODES								
EMPIDIDAE	4	1	1	1	4	2	1	3
CERATOPOGONIDAE					1	1		4
PSYCHODIDAE								
MUSCIDAE								
DIXIDAE								
LIMNEPHILIDAE								
GLOSSOMATIDAE								
COLLEMBOLA	1	2	1					
OLIGOCHAETA	12	4	7	1		1	15	3
NEMATODA			2					
PLATYHELMINTHES								
HYDRACARINA		1	1	4	1	1	1	1
COPEPODA				1		1		6
CLADOCERA								
UNID. PLECOPTERA				5				
UNID. EPHEMEROPTERA				1		28	16	7
UNID. DIPTERA		1				1		

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TAXA	S 17	S 18	S 19	S 20	S 21	S 22	S 23	S 24
NEMOURA	25		1			1	4	1
PODMOSTA								
ZAPADA								2
CHLOROPERLIDAE			21	14	6	3	12	13
ALLOPERLA								
PERLODIDAE			4	8			9	2
ISOPERLA					1			
CAPNIIDAE	37	11	34	5		15	35	14
TAENIOPTERYGIDAE								
BAETIDAE					3			
BAETIS			3	1		4	3	2
PSEUDOCLEON								
EPHEMERELLA								
SERRATELLA							1	
HEPTAGENIIDAE								
CINYGMULA			17	5	13	11	14	6
EPEORUS			49	18	25	14	25	10
AMELETUS								
CHIRONOMIDAE	60	22	47	109	73	82	34	326
CHIRONOMIDAE (PUPAE)	1		1		2			
GYMNOPAIS								
PROSIMULIUM	9	2		2				11
SIMULIIDAE (PUPAE)								1
TIPULIDAE								
TIPULA								
DICRANOTA								
ORMOSIA								
GONOMYODES								
EMPIDIDAE	2	4		1		1		1
CERATOPOGONIDAE								
PSYCHODIDAE								
MUSCIDAE								
DIXIDAE								
LIMNEPHILIDAE								
GLOSSOMATIDAE								
COLLEMBOLA			1	1	1	1	2	7
OLIGOCHAETA	65	24	4	10	26	16	3	14
NEMATODA								
PLATYHELMINTHES								
HYDRACARINA		1		6		4		5
COPEPODA								2
CLADOCERA						1		
UNID. PLECOPTERA								
UNID. EPHEMEROPTERA	12	2	61	8	30	16	30	31
UNID. DIPTERA		1		1		1		

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TAXA	S 25	S 26	S 27	S 28	S 29	S 30	S 31	S 32
NEMOURA	2	3	1	12	1	4	28	9
PODMOSTA	100		1	12	7	9		1
ZAPADA	18	2		1		1		
CHLOROPERLIDAE	4	4	1	6		8		1
ALLOPERLA								
PERLODIDAE								
ISOPERLA								
CAPNIIDAE	208	374	52	347	165	303	36	41
TAENIOPTERYGIDAE								
BAETIDAE								
BAETIS				1				
PSEUDOCLEON								
EPHEMERELLA								
SERRATELLA								
HEPTAGENIIDAE								
CINYGMULA							1	
EPEORUS								1
AMELETUS	23	3		3	1	1		
CHIRONOMIDAE	644	171	33	247	79	255	5	43
CHIRONOMIDAE (PUPAE)	3			1	1	3	2	3
GYMNOPAIS		3		6		3		
PROSIMULIUM				1			1	
SIMULIIDAE (PUPAE)								
TIPULIDAE	11							
TIPULA	1	1					1	
DICRANOTA	2			2		1		
ORMOSIA								
GONOMYODES					2			
EMPIDIDAE								13
CERATOPOGONIDAE								
PSYCHODIDAE								
MUSCIDAE							1	
DIXIDAE								
LIMNEPHILIDAE								
GLOSSOMATIDAE								
COLLEMBOLA	7			4	3			
OLIGOCHAETA	222	10	9	9	55	140	21	19
NEMATODA	2			1				
PLATYHELMINTHES	5	2		1				
HYDRACARINA	1	4		2	1	2	1	1
COPEPODA	25	3		1	4	1		
CLADOCERA								
UNID. PLECOPTERA								
UNID. EPHEMEROPTERA	1	4	3		1	1		
UNID. DIPTERA	2	1	1					

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TAXA	S 33	S 34	S 35	S 36	S 37	S 38	S 39	S 40
NEMOURA	9	24	26	55	15	3	1	3
PODMOSTA	1	3	3	12				
ZAPADA								
CHLOROPERLIDAE								
ALLOPERLA								
PERLODIDAE								
ISOPERLA								
CAPNIIDAE	33	46	30	57	2	1		3
TAENIOPTERYGIDAE								
BAETIDAE							2	
BAETIS								
PSEUDOCLEON								
EPHEMERELLA								
SERRATELLA								
HEPTAGENIIDAE								
CINYGMULA						1		
EPEORUS								
AMELETUS								
CHIRONOMIDAE	12	45	19	47	57	13	10	3
CHIRONOMIDAE (PUPAE)		6	2	4				
GYMNOPAIS								
PROSIMULIUM		1	2		1			
SIMULIIDAE (PUPAE)								
TIPULIDAE								
TIPULA								
DICRANOTA								
ORMOSIA								
GONOMYODES								
EMPIDIDAE		1	2	1	1		4	
CERATOPOGONIDAE								
PSYCHODIDAE								
MUSCIDAE								
DIXIDAE								
LIMNEPHILIDAE								
GLOSSOMATIDAE								
COLLEMBOLA		1	2	2	2		1	
OLIGOCHAETA	5	33	6	15	2	1	3	2
NEMATODA								
PLATYHELMINTHES							1	
HYDRACARINA	2	1		1				
COPEPODA	1		1					
CLADOCERA								
UNID. PLECOPTERA								
UNID. EPHEMEROPTERA								1
UNID. DIPTERA					1			

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TAXA	S 41	S 42	S 43	S 44	S 45	S 46	S 47	S 48
NEMOURA	8	2	2			21		
PODMOSTA								
ZAPADA								
CHLOROPERLIDAE			6	3	4	9		3
ALLOPERLA								
PERLODIDAE								
ISOPERLA								
CAPNIIDAE	5	2	2			12		
TAENIOPTERYGIDAE								
BAETIDAE	1				1			
BAETIS								1
PSEUDOCLEON								
EPHEMERELLA					1			
SERRATELLA								
HEPTAGENIIDAE						3		1
CINYGMULA					2			2
EPEORUS				1	12			1
AMELETUS								
CHIRONOMIDAE	7	30	71	3	16	30	8	7
CHIRONOMIDAE (PUPAE)	2		1		1	2	2	
GYMNOPAIS								
PROSIMULIUM								
SIMULIIDAE (PUPAE)								
TIPULIDAE				2	1	1		
TIPULA								
DICRANOTA					1			
ORMOSIA								
GONOMYODES								
EMPIDIDAE		2		1	2	6	1	
CERATOPOGONIDAE								
PSYCHODIDAE								
MUSCIDAE								
DIXIDAE			1					
LIMNEPHILIDAE					1			1
GLOSSOMATIDAE								
COLLEMBOLA			4			2	1	
OLIGOCHAETA	5	1		1	4			
NEMATODA								
PLATYHELMINTHES	1	1						
HYDRACARINA		1	10	1	1			2
COPEPODA			3				1	
CLADOCERA								
UNID. PLECOPTERA								
UNID. EPHEMEROPTERA			3			18		
UNID. DIPTERA								

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TAXA	S 49	S 50	S 51	S 52	S 53	S 54	S 55	S 56
NEMOURA	4	2	18	3	4	8	49	36
PODMOSTA								
ZAPADA			3		1	1	1	
CHLOROPERLIDAE	10	12	13	2	5	9		
ALLOPERLA								
PERLODIDAE		2	3				1	1
ISOPERLA								1
CAPNIIDAE	170	72	365	21	77	92	62	36
TAENIOPTERYGIDAE								
BAETIDAE								
BAETIS								
PSEUDOCLEON								
EPHEMERELLA								
SERRATELLA								
HEPTAGENIIDAE							1	
CINYGMULA								
EPEORUS								
AMELETUS	2	5		3				
CHIRONOMIDAE	19	75	139	22	57	25	40	50
CHIRONOMIDAE (PUPAE)		5	23		2	3	6	4
GYMNOPAIS	3	9	9	2	6			
PROSIMULIUM			2			1	1	
SIMULIIDAE (PUPAE)								
TIPULIDAE			2	1	1			
TIPULA		1	3			1	1	
DICRANOTA	5		2	2			3	2
ORMOSIA								
GONOMYODES								
EMPIDIDAE	2	2					1	
CERATOPOGONIDAE								
PSYCHODIDAE	1							
MUSCIDAE								
DIXIDAE								
LIMNEPHILIDAE		1						
GLOSSOMATIDAE								
COLLEMBOLA	1	1	2		1	3	1	1
OLIGOCHAETA	209	300	90	70	93	48	9	14
NEMATODA	2	6	2	1		2		
PLATYHELMINTHES	6	13	10	1	14	5		2
HYDRACARINA	2	2	4	1	3	3		4
COPEPODA		1				1	2	
CLADOCERA								
UNID. PLECOPTERA								
UNID. EPHEMEROPTERA	1							
UNID. DIPTERA								

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TAXA	S 57	S 58	S 59	S 60	S 61	S 62	S 63	S 64
NEMOURA	8	47	10	75	13	12	8	13
PODMOSTA		1						
ZAPADA								
CHLOROPERLIDAE	1				1	1	1	
ALLOPERLA								
PERLODIDAE	3	1	2					
ISOPERLA								
CAPNIIDAE	98	198	16	59	16	23	41	35
TAENIOPTERYGIDAE					1	1		
BAETIDAE								
BAETIS					1	2		1
PSEUDOCLEON								
EPHEMERELLA								
SERRATELLA								
HEPTAGENIIDAE					14	4	35	9
CINYGMULA	1	1			1			
EPEORUS								
AMELETUS								
CHIRONOMIDAE	38	45	32	132	82	61	87	51
CHIRONOMIDAE (PUPAE)	3	2	3	6	3	4	2	
GYMNOPAIS				1				
PROSIMULIUM				2				
SIMULIIDAE (PUPAE)		1						
TIPULIDAE	1							1
TIPULA	2	1	1	3				
DICRANOTA		2						
ORMOSIA								
GONOMYODES								
EMPIDIDAE	1	1	14			4	3	6
CERATOPOGONIDAE	2							
PSYCHODIDAE			3					
MUSCIDAE								
DIXIDAE								
LIMNEPHILIDAE		1	1	1				
GLOSSOMATIDAE								
COLLEMBOLA	3	2	1	3		1		2
OLIGOCHAETA	64	74	14	26	2	14	115	22
NEMATODA				1				
PLATYHELMINTHES	1							
HYDRACARINA	4	2	1	1			1	
COPEPODA	1	2		1			1	
CLADOCERA								
UNID. PLECOPTERA								
UNID. EPHEMEROPTERA								
UNID. DIPTERA	2			3			1	

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TAXA	S 65	S 66	S 67	S 68	S 69	S 70	S 71	S 72
NEMOURA	4	23	2	6	1		2	1
PODMOSTA								
ZAPADA								
CHLOROPERLIDAE				1	4	1	5	6
ALLOPERLA								
PERLODIDAE							1	1
ISOPERLA					2			
CAPNIIDAE	17	15	4	4	16	4	42	27
TAENIOPTERYGIDAE			3	20	9	5	48	29
BAETIDAE							2	1
BAETIS		1			1	2	1	
PSEUDOCLEON			1					
EPHEMERELLA					1			1
SERRATELLA							4	
HEPTAGENIIDAE	16	35		8	13	5	36	41
CINYGMULA				1			1	2
EPEORUS			1	7		2	3	7
AMELETUS								
CHIRONOMIDAE	36	136	19	19	5	54	58	26
CHIRONOMIDAE (PUPAE)		2	1		1	2	1	1
GYMNOPAIS								
PROSIMULIUM		1		2	2	4	5	5
SIMULIIDAE (PUPAE)								
TIPULIDAE		1				1		
TIPULA	1	1						
DICRANOTA								
ORMOSIA								
GONOMYODES								
EMPIDIDAE	4	5		1	1		2	
CERATOPOGONIDAE	1							
PSYCHODIDAE								
MUSCIDAE								
DIXIDAE								
LIMNEPHILIDAE								
GLOSSOMATIDAE			1			1		1
COLLEMBOLA	1	1		2	1	1	2	1
OLIGOCHAETA	7	18	1		3		2	
NEMATODA								
PLATYHELMINTHES	1							
HYDRACARINA	1			3	1		6	
COPEPODA		1	1					
CLADOCERA								
UNID. PLECOPTERA								
UNID. EPHEMEROPTERA							1	
UNID. DIPTERA								

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APPENDIX C

Biovolume (in milliliters) of organisms of each taxon found in each sample ($0.1\ m^2$). Trace values (< 0.001 ml) are not indicated. Site information for each sample number is given in appendix A.

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TAXA	S 1	S 2	S 3	S 4	S 5	S 6	S 7	S 8
NEMOURA							0.006	0.001
PODMOSTA	0.011	0.007	0.014	0.03	0.012	0.015	0.006	0.005
ZAPADA								
CHLOROPERLIDAE		0.038	0.025	0.032	0.015	0.018		
ALLOPERLA								
PERLODIDAE								
ISOPERLA								
CAPNIIDAE	0.001	0.001		0.001	0.002		0.011	0.001
TAENIOPTERYGIDAE								
BAETIDAE								
BAETIS								
PSEUDOCLEON								
EPHEMERELLA								
SERRATELLA								
HEPTAGENIIDAE								
CINYGMULA			0.001	0.001				
EPEORUS								
AMELETUS	0.003	0.06	0.035	0.01	0.01	0.01		
CHIRONOMIDAE	0.001	0.021	0.002	0.002	0.004	0.004	0.018	0.009
CHIRONOMIDAE (PUPAE)								
GYMNOPAIS								
PROSIMULIUM								
SIMULIIDAE (PUPAE)								
TIPULIDAE					0.012			
TIPULA		0.05			0.03			
DICRANOTA	0.006	0.195	0.015	0.02	0.006	0.005	0.002	
ORMOSIA								
GONOMYODES		0.001						
EMPIDIDAE							0.001	
CERATOPOGONIDAE								
PSYCHODIDAE								
MUSCIDAE								
DIXIDAE								
LIMNEPHILIDAE								
GLOSSOMATIDAE								
COLLEMBOLA				0.001		0.003		
OLIGOCHAETA		0.003	0.007		0.015		0.008	
NEMATODA								
PLATYHELMINTHES								
HYDRACARINA								
COPEPODA								
CLADOCERA								
UNID. PLECOPTERA								
UNID. EPHEMEROPTERA		0.002						
UNID. DIPTERA								

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TAXA	S 9	S 10	S 11	S 12	S 13	S 14	S 15	S 16
NEMOURA	0.015	0.008	0.005	0.006		0.001	0.001	
PODMOSTA	0.06	0.004	0.001	0.001				
ZAPADA								
CHLOROPERLIDAE								
ALLOPERLA								
PERLODIDAE								
ISOPERLA								
CAPNIIDAE	0.018	0.012		0.01		0.011	0.002	0.001
TAENIOPTERYGIDAE								
BAETIDAE								
BAETIS								
PSEUDOCLEON								
EPHEMERELLA								
SERRATELLA								
HEPTAGENIIDAE								
CINYGMULA	0.001							
EPEORUS								
AMELETUS	0.007	0.002	0.01					
CHIRONOMIDAE	0.01	0.02	0.003	0.02	0.002	0.002	0.01	0.002
CHIRONOMIDAE (PUPAE)								
GYMNOPAIS								
PROSIMULIUM								
SIMULIIDAE (PUPAE)								
TIPULIDAE								
TIPULA	0.382	0.16						
DICRANOTA								
ORMOSIA								
GONOMYODES								
EMPIDIDAE	0.002				0.001	0.001		0.001
CERATOPOGONIDAE								
PSYCHODIDAE								
MUSCIDAE								
DIXIDAE								
LIMNEPHILIDAE								
GLOSSOMATIDAE								
COLLEMBOLA								
OLIGOCHAETA	0.008	0.001	0.001				0.008	0.002
NEMATODA								
PLATYHELMINTHES								
HYDRACARINA								
COPEPODA								
CLADOCERA								
UNID. PLECOPTERA								
UNID. EPHEMEROPTERA								
UNID. DIPTERA		0.001						

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TAXA	S 17	S 18	S 19	S 20	S 21	S 22	S 23	S 24
NEMOURA	0.006							
PODMOSTA		0.001						
ZAPADA								
CHLOROPERLIDAE			0.02	0.002	0.003	0.005	0.016	0.01
ALLOPERLA								
PERLODIDAE					0.006			
ISOPERLA								
CAPNIIDAE	0.012	0.002						
TAENIOPTERYGIDAE								
BAETIDAE								
BAETIS			0.002	0.001	0.01	0.005	0.002	0.004
PSEUDOCLEON								
EPHEMERELLA							0.015	
SERRATELLA								
HEPTAGENIIDAE								
CINYGMULA			0.042	0.008	0.01	0.02	0.025	0.013
EPEORUS			0.015	0.002	0.007	0.003	0.005	0.002
AMELETUS								
CHIRONOMIDAE	0.001	0.005	0.003	0.007	0.005	0.006	0.002	0.021
CHIRONOMIDAE (PUPAE)								
GYMNOPAIS								
PROSIMULIUM								0.005
SIMULIIDAE (PUPAE)								
TIPULIDAE								
TIPULA								
DICRANOTA								
ORMOSIA								
GONOMYODES								
EMPIDIDAE	0.002	0.001						
CERATOPOGONIDAE								
PSYCHODIDAE								
MUSCIDAE								
DIXIDAE								
LIMNEPHILIDAE								
GLOSSOMATIDAE								
COLLEMBOLA								
OLIGOCHAETA	0.02	0.003		0.001	0.003	0.001		0.005
NEMATODA								
PLATYHELMINTHES								
HYDRACARINA				0.001				
COPEPODA								
CLADOCERA								
UNID. PLECOPTERA								
UNID. EPHEMEROPTERA					0.001			0.001
UNID. DIPTERA								

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TAXA	S 25	S 26	S 27	S 28	S 29	S 30	S 31	S 32
NEMOURA		0.001		0.002		0.001	0.004	0.002
PODMOSTA	0.13			0.012	0.01	0.01		0.001
ZAPADA	0.013	0.001		0.001		0.002		
CHLOROPERLIDAE	0.01	0.014	0.004	0.009		0.001		
ALLOPERLA								
PERLODIDAE								
ISOPERLA								
CAPNIIDAE	0.011	0.011	0.004	0.012	0.008	0.019	0.005	0.009
TAENIOPTERYGIDAE								
BAETIDAE								
BAETIS				0.01				
PSEUDOCLEON								
EPHEMERELLA								
SERRATELLA								
HEPTAGENIIDAE								
CINYGMULA							0.001	
EPEORUS								
AMELETUS	0.02	0.012		0.02		0.01		
CHIRONOMIDAE	0.03	0.011	0.002	0.023	0.006	0.025	0.001	0.002
CHIRONOMIDAE (PUPAE)								
GYMNOPAIS								
PROSIMULIUM							0.001	
SIMULIIDAE (PUPAE)								
TIPULIDAE	0.017							
TIPULA	0.028						0.032	
DICRANOTA								
ORMOSIA								
GONOMYODES					0.001			
EMPIDIDAE								0.006
CERATOPOGONIDAE								
PSYCHODIDAE								
MUSCIDAE							0.006	
DIXIDAE								
LIMNEPHILIDAE								
GLOSSOMATIDAE								
COLLEMBOLA								
OLIGOCHAETA	0.08	0.015	0.005	0.01	0.038	0.05	0.007	0.009
NEMATODA								
PLATYHELMINTHES	0.006	0.002		0.001				
HYDRACARINA								
COPEPODA								
CLADOCERA								
UNID. PLECOPTERA								
UNID. EPHEMEROPTERA								
UNID. DIPTERA								

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TAXA	S 33	S 34	S 35	S 36	S 37	S 38	S 39	S 40
NEMOURA	0.001	0.004	0.002	0.009	0.006	0.001		0.001
PODMOSTA	0.001	0.001	0.004	0.012				
ZAPADA								
CHLOROPERLIDAE								
ALLOPERLA								
PERLODIDAE								
ISOPERLA								
CAPNIIDAE	0.005	0.007	0.004	0.009	0.001			
TAENIOPTERYGIDAE								
BAETIDAE								
BAETIS								
PSEUDOCLEON								
EPHEMERELLA								
SERRATELLA								
HEPTAGENIIDAE								
CINYGMULA						0.001		
EPEORUS								
AMELETUS								
CHIRONOMIDAE	0.001	0.005		0.004	0.009	0.001	0.001	
CHIRONOMIDAE (PUPAE)								
GYMNOPAIS								
PROSIMULIUM								
SIMULIIDAE (PUPAE)								
TIPULIDAE								
TIPULA								
DICRANOTA								
ORMOSIA								
GONOMYODES								
EMPIDIDAE				0.001				
CERATOPOGONIDAE								
PSYCHODIDAE								
MUSCIDAE								
DIXIDAE								
LIMNEPHILIDAE								
GLOSSOMATIDAE								
COLLEMBOLA								
OLIGOCHAETA	0.002	0.015		0.02			0.001	0.001
NEMATODA								
PLATYHELMINTHES								
HYDRACARINA								
COPEPODA								
CLADOCERA								
UNID. PLECOPTERA								
UNID. EPHEMEROPTERA								
UNID. DIPTERA								

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TAXA	S 41	S 42	S 43	S 44	S 45	S 46	S 47	S 48
NEMOURA	0.002	0.001						
PODMOSTA								
ZAPADA								
CHLOROPERLIDAE				0.001	0.006	0.007		0.004
ALLOPERLA								
PERLODIDAE								
ISOPERLA								
CAPNIIDAE								
TAENIOPTERYGIDAE								
BAETIDAE								
BAETIS								0.002
PSEUDOCLEON								
EPHEMERELLA								
SERRATELLA								
HEPTAGENIIDAE						0.001		
CINYGMULA					0.006			0.006
EPEORUS					0.01			
AMELETUS								
CHIRONOMIDAE		0.002	0.004		0.001	0.002		0.001
CHIRONOMIDAE (PUPAE)								
GYMNOPAIS								
PROSIMULIUM								
SIMULIIDAE (PUPAE)								
TIPULIDAE								
TIPULA					0.001			
DICRANOTA					0.007			
ORMOSIA								
GONOMYODES								
EMPIDIDAE						0.001		
CERATOPOGONIDAE								
PSYCHODIDAE								
MUSCIDAE								
DIXIDAE								
LIMNEPHILIDAE								
GLOSSOMATIDAE								
COLLEMBOLA								
OLIGOCHAETA	0.003			0.001	0.002			
NEMATODA								
PLATYHELMINTHES								
HYDRACARINA								
COPEPODA								
CLADOCERA								
UNID. PLECOPTERA								
UNID. EPHEMEROPTERA								
UNID. DIPTERA								

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TAXA	S 49	S 50	S 51	S 52	S 53	S 54	S 55	S 56
NEMOURA	0.009	0.001	0.005		0.001	0.011	0.033	0.02
PODMOSTA								
ZAPADA								
CHLOROPERLIDAE	0.008	0.005	0.01	0.002	0.005	0.008		
ALLOPERLA								
PERLODIDAE								0.005
ISOPERLA								
CAPNIIDAE	0.016	0.009	0.035	0.003	0.011	0.01	0.01	0.009
TAENIOPTERYGIDAE								
BAETIDAE								
BAETIS								
PSEUDOCLEON								
EPHEMERELLA								
SERRATELLA								
HEPTAGENIIDAE								
CINYGMULA								
EPEORUS								
AMELETUS	0.012	0.012		0.03				
CHIRONOMIDAE	0.011	0.017	0.098	0.01	0.025	0.006	0.005	0.01
CHIRONOMIDAE (PUPAE)		0.001	0.007					0.002
GYMNOPAIS	0.011	0.025	0.02	0.007	0.015			
PROSIMULIUM								
SIMULIIDAE (PUPAE)								
TIPULIDAE								
TIPULA		0.162	0.108			0.025	0.008	
DICRANOTA	0.002						0.005	0.001
ORMOSIA								
GONOMYODES								
EMPIDIDAE	0.008	0.006						
CERATOPOGONIDAE								
PSYCHODIDAE								
MUSCIDAE								
DIXIDAE								
LIMNEPHILIDAE								
GLOSSOMATIDAE								
COLLEMBOLA								
OLIGOCHAETA	0.142	0.14	0.25	0.04	0.072	0.022	0.013	0.01
NEMATODA								
PLATYHELMINTHES	0.008	0.01	0.007		0.011	0.003		0.004
HYDRACARINA								
COPEPODA								
CLADOCERA								
UNID. PLECOPTERA								
UNID. EPHEMEROPTERA								
UNID. DIPTERA								

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TAXA	S 57	S 58	S 59	S 60	S 61	S 62	S 63	S 64
NEMOURA	0.005	0.017	0.01	0.07	0.017	0.001	0.007	0.007
PODMOSTA								
ZAPADA								
CHLOROPERLIDAE								
ALLOPERLA								
PERLODIDAE								
ISOPERLA								
CAPNIIDAE	0.016	0.021	0.002	0.014	0.002	0.004	0.007	0.005
TAENIOPTERYGIDAE								
BAETIDAE								
BAETIS					0.001	0.002		0.002
PSEUDOCLEON								
EPHEMERELLA								
SERRATELLA								
HEPTAGENIIDAE								
CINYGMULA	0.006	0.005			0.009			
EPEORUS								
AMELETUS								
CHIRONOMIDAE	0.005	0.01	0.003	0.035	0.014	0.006	0.011	0.009
CHIRONOMIDAE (PUPAE)								
GYMNOPAIS								
PROSIMULIUM				0.006				
SIMULIIDAE (PUPAE)		0.002						
TIPULIDAE								
TIPULA	0.027		0.028	0.275				
DICRANOTA								
ORMOSIA								
GONOMYODES								
EMPIDIDAE		0.001	0.003					0.002
CERATOPOGONIDAE								
PSYCHODIDAE								
MUSCIDAE								
DIXIDAE								
LIMNEPHILIDAE								
GLOSSOMATIDAE								
COLLEMBOLA								
OLIGOCHAETA	0.098	0.025	0.002	0.015	0.001	0.006	0.038	0.125
NEMATODA								
PLATYHELMINTHES								
HYDRACARINA				0.001				
COPEPODA								
CLADOCERA								
UNID. PLECOPTERA								
UNID. EPHEMEROPTERA							0.001	
UNID. DIPTERA								

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TAXA	S 65	S 66	S 67	S 68	S 69	S 70	S 71	S 72
NEMOURA		0.02					0.011	0.006
PODMOSTA								
ZAPADA								
CHLOROPERLIDAE					0.002	0.001	0.001	0.001
ALLOPERLA								
PERLODIDAE					0.002		0.001	0.001
ISOPERLA								
CAPNIIDAE	0.003	0.003		0.001	0.003		0.011	0.008
TAENIOPTERYGIDAE				0.001				
BAETIDAE							0.003	0.003
BAETIS		0.001			0.002	0.003	0.002	
PSEUDOCLEON			0.003					
EPHEMERELLA								
SERRATELLA							0.005	
HEPTAGENIIDAE							0.001	
CINYGMULA				0.009			0.002	0.003
EPEORUS			0.006	0.022		0.011	0.015	0.022
AMELETUS								
CHIRONOMIDAE	0.001	0.03	0.006	0.003		0.012	0.022	0.001
CHIRONOMIDAE (PUPAE)							0.001	
GYMNOPAIS								
PROSIMULIUM		0.001		0.001		0.003		
SIMULIIDAE (PUPAE)								
TIPULIDAE								
TIPULA	0.052	0.025						
DICRANOTA								
ORMOSIA								
GONOMYODES								
EMPIDIDAE	0.001	0.001						
CERATOPOGONIDAE								
PSYCHODIDAE								
MUSCIDAE								
DIXIDAE								
LIMNEPHILIDAE								
GLOSSOMATIDAE								
COLLEMBOLA								
OLIGOCHAETA	0.002	0.014						
NEMATODA								
PLATYHELMINTHES								
HYDRACARINA								
COPEPODA								
CLADOCERA								
UNID. PLECOPTERA				0.002				
UNID. EPHEMEROPTERA		0.001						0.001
UNID. DIPTERA								

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APPENDIX D

Gut contents from taxa selected for gut analyses. HCW = head capsule width, BL = body length, size is in millimeters.

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TAXA	DATE	SITE	SAMPLE	SIZE	GUT CONTENTS
PLECOPTERA:					
CAPNIIDAE	JUNE	2	S 9	HCW=0.76	100% FPOM;tr.CPOM;tr.ANIMAL
CAPNIIDAE	JUNE	2	S 9	HCW=0.68	100% CPOM
CAPNIIDAE	JULY	1	S 28	HCW=0.66	100% FPOM;tr.CPOM;tr.DIATOMS
CAPNIIDAE	JULY	2	S 32	HCW=0.72	100% FPOM;tr.CPOM;tr.DIATOMS
CAPNIIDAE	AUG.	4	S 72	HCW=0.60	100% FPOM;tr.DIATOMS
CAPNIIDAE	AUG.	4	S 72	HCW=0.52	100% FPOM;tr.DIATOMS
CHLOROPERLIDAE	JUNE	1	S 2	HCW=1.12	100% ANIMAL (CHIRO.)
CHLOROPERLIDAE	JUNE	1	S 2	HCW=1.12	100% ANIMAL (CHIRO. & UNID.)
CHLOROPERLIDAE	JULY	1	S 25	HCW=1.00	100% ANIMAL (CHIRO.)
CHLOROPERLIDAE	JULY	4	S 45	HCW=1.08	100% ANIMAL (CHIRO. & UNID.)
CHLOROPERLIDAE	AUG.	4	S 71	HCW=0.70	100% ANIMAL
CHLOROPERLIDAE	AUG.	1	S 51	HCW=0.76	100% ANIMAL
ISOPERLA	JULY	1	S 30	HCW=0.40	tr. DETRITUS (UNRECOGNIZABLE)
ISOPERLA	JULY	3	S 39	HCW=0.72	100% ANIMAL (CHIRO.)
ISOPERLA	AUG.	2	S 58	HCW=0.96	100% ANIMAL (CHIRO. & NEMOURID)
ISOPERLA	AUG.	2	S 59	HCW=1.28	100% ANIMAL (CHIRO.)
ISOPERLA	AUG.	4	S 69	HCW=0.92	100% ANIMAL (CHIRO. & NEMOURID)
NEMOURA	JUNE	2	S 10	HCW=1.12	100% CPOM
NEMOURA	JUNE	2	S 11	HCW=1.20	100% CPOM;tr.ANIMAL
NEMOURA	JULY	1	S 28	HCW=0.80	100% FPOM (GUT NEAR EMPTY)
NEMOURA	JULY	3	S 42	HCW=0.72	100% FPOM;tr.CPOM (GUT NEAR EM.)
NEMOURA	AUG.	1	S 49	HCW=1.28	EMPTY GUT
NEMOURA	AUG.	1	S 54	HCW=1.12	EMPTY GUT
NEMOURA	AUG.	1	S 51	HCW=1.16	EMPTY GUT
NEMOURA	AUG.	4	S 71	HCW=0.64	100% CPOM
PODMOSTA	JUNE	1	S 1	HCW=0.92	100% CPOM
PODMOSTA	JUNE	1	S 1	HCW=0.88	100% CPOM
PODMOSTA	JUNE	1	S 6	HCW=0.92	100% CPOM
PODMOSTA	JULY	1	S 25	HCW=0.84	100% CPOM
PODMOSTA	JULY	1	S 28	HCW=0.84	100% CPOM
PODMOSTA	JULY	1	S 29	HCW=0.92	100% CPOM
TAENIOPTERYGIDAE	AUG.	4	S 69	HCW=0.42	100% FPOM;tr.DIATOMS
TAENIOPTERYGIDAE	AUG.	4	S 69	HCW=0.44	100% FPOM;tr.DIATOMS
TAENIOPTERYGIDAE	AUG.	4	S 71	HCW=0.48	100% FPOM;tr.DIATOMS
TAENIOPTERYGIDAE	AUG.	4	S 71	HCW=0.40	100% FPOM;tr.DIATOMS
TAENIOPTERYGIDAE	AUG.	4	S 72	HCW=0.54	100% FPOM;tr.DIATOMS
TAENIOPTERYGIDAE	AUG.	4	S 72	HCW=0.42	100% FPOM;tr.DIATOMS
ZAPADA	JUNE	1	S 2	HCW=0.88	100% CPOM;tr.DIATOMS;tr.ANIMALS
ZAPADA	JUNE	2	S 9	HCW=0.72	100% CPOM;tr.DIATOMS
ZAPADA	JULY	1	S 25	HCW=1.36	100% CPOM
ZAPADA	JULY	1	S 25	HCW=1.16	100% CPOM
ZAPADA	JULY	1	S 25	HCW=1.20	100% CPOM

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TAXA	DATE	SITE	SAMPLE	SIZE	GUT CONTENTS
EPHEMEROPTERA:					
AMELETUS	JUNE	1	S 2	HCW=1.28	100% FPOM;tr.DIATOMS
AMELETUS	JUNE	1	S 2	HCW=1.40	100% FPOM;tr.DIATOMS
AMELETUS	JULY	1	S 25	HCW=1.44	100% FPOM;tr.DIATOMS
AMELETUS	JULY	1	S 26	HCW=1.24	100% FPOM;tr.DIATOMS
AMELETUS	AUG.	1	S 50	HCW=0.92	80% DIATOMS;20% FPOM
AMELETUS	AUG.	1	S 50	HCW=0.76	20% DIATOMS;80% FPOM
BAETIS	JUNE	4	S 22	HCW=1.00	70% DIATOMS;30% FPOM
BAETIS	JUNE	4	S 22	HCW=0.84	80% DIATOMS;20% FPOM
BAETIS	JULY	4	S 48	HCW=0.84	20% DIATOMS;80% FPOM
BAETIS	AUG.	4	S 70	HCW=0.60	100% FPOM;tr.DIATOMS
BAETIS	AUG.	4	S 70	HCW=0.84	50% FPOM;50% DIATOMS
EPEORUS	JUNE	4	S 24	HCW=1.20	40% DIATOMS;60% FPOM
EPEORUS	JULY	4	S 45	HCW=1.52	100% FPOM;tr.DIATOMS
EPEORUS	AUG.	4	S 72	HCW=1.68	10% DIATOMS;90% FPOM
EPEORUS	AUG.	4	S 68	HCW=1.88	100% FPOM;tr.DIATOMS
EPHEMERELLA	JUNE	4	S 23	HCW=1.92	100% CPOM;tr.DIATOMS
EPHEMERELLA	AUG.	4	S 71	HCW=0.76	100% CPOM;tr.DIATOMS
EPHEMERELLA	AUG.	4	S 71	HCW=0.72	100% CPOM;tr.DIATOMS
DIPTERA:					
EMPIDIDAE	JUNE	3	S 13	BL=4.92	100% ANIMAL
EMPIDIDAE	JUNE	2	S 9	BL=7.00	100% ANIMAL
EMPIDIDAE	JULY	2	S 32	BL=3.00	100% ANIMAL
EMPIDIDAE	JULY	2	S 32	BL=2.92	100% ANIMAL
EMPIDIDAE	JULY	2	S 32	BL=2.20	100% ANIMAL
EMPIDIDAE	AUG.	1	S 50	BL=9.13	100% ANIMAL
DICRANOTA	JUNE	1	S 2	BL=13.0	100% ANIMAL (CHIRO.)
DICRANOTA	JUNE	1	S 2	BL=12.0	100% ANIMAL (CHIRO.)
DICRANOTA	JUNE	1	S 2	BL=12.5	100% ANIMAL (CHIRO.)
ORMOSIA	JULY	1	S 25	BL=1.0	100% CPOM
ORMOSIA	JULY	1	S 25	BL=6.3	100% CPOM
TIPULA	JUNE	2	S 9	BL=36.0	100% CPOM
TIPULA	JUNE	2	S 10	BL=26.0	100% CPOM
TIPULA	JULY	1	S 25	BL=15.0	100% CPOM;tr.ANIMAL
TIPULA	AUG.	1	S 51	BL=18.0	100% CPOM
TIPULA	AUG.	1	S 51	BL=13.0	100% CPOM
TIPULA	AUG.	2	S 60	BL=30.0	100% CPOM

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